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**APPLICATION
FOR
UNITED STATES
LETTERS PATENT**

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FOR: **ARRAYED WAVEGUIDE GRADING
WITH OPTICAL INPUT AND OUTPUT
CHARACTERISTICS SETTABLE TO
DESIRED VALUES**

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ARRAYED WAVEGUIDE GRADING WITH OPTICAL INPUT AND OUTPUT
CHARACTERISTICS SETTABLE TO DESIRED VALUES

BACKGROUND OF THE INVENTION

5 1. Field of the Invention:

The present invention relates to an arrayed
waveguide grating or a waveguide device having a slab
waveguide, a demultiplexer or a multiplexer which employs
an arrayed waveguide grating or a waveguide device, and
10 an optical communication system which employs an arrayed
waveguide grating or a waveguide device or a demulti-
plexer or a multiplexer.

2. Description of the Related Art:

As the volume of data to be transmitted over an op-
15 tical fiber communication system increases, it is desired
that the optical fiber communication system have an in-
creased capacity for data transmission. In view of such
a demand, growing importance is attached to optical wave-
length filters for use as multiplexing and demultiplexing
20 devices for multiplexing and demultiplexing wavelengths
in DWDM (Dense Wavelength Division Multiplexing) communi-
cation systems.

Optical wavelength filters are available in various
types. Of the various wavelength filters, an arrayed
25 waveguide grating (AWG) has a narrow wavelength band and
a high extinction ratio, and has features as a multi-

input, multi-output filter device. The arrayed waveguide grating is capable of demultiplexing multiplexed signals and multiplexing signals, and can easily be used to make up wavelength multiplexing and demultiplexing devices.

5 Fig. 1 of the accompanying drawings shows an overall arrangement of a conventional arrayed waveguide grating. As shown in Fig. 1, the conventional arrayed waveguide grating, generally denoted by 11, comprises substrate 12, one or plural input waveguides 13 disposed
10 on substrate 12, a plurality of output waveguides 14 disposed on substrate 12, channel waveguide array 15 disposed on substrate 12, and curved in a certain direction with respective curvatures, inlet slab waveguide 16 disposed on substrate 12, and connecting input waveguides 13
15 to channel waveguide array 15, and outlet slab waveguide 17 disposed on substrate 12, and connecting channel waveguide array 15 to output waveguides 14. Multiplexed signal light entered from input waveguides 13 is spread by inlet slab waveguide 16, and enters into channel
20 waveguide array 15.

Channel waveguide array 15 comprises a plurality of arrayed waveguides having respective different optical path lengths which are successively longer or shorter. Therefore, signal light beams guided through the respective
25 arrayed waveguides couple in respective different phases spaced at certain intervals to the outlet slab

5 waveguide 17. Since the signal light beams actually suffer chromatic dispersion, the cophasal surfaces of the signal light beams are inclined depending on the wavelength. As a result, the signal light beams are focused (converged) at different positions corresponding to the difference wavelengths on the interface between the outlet slab waveguide 17 and the output waveguides 14. Since the output waveguides 14 are disposed in the respective positions corresponding to the difference wavelengths, desired wavelengths can be extracted from the respective output waveguides 14. The slab waveguides are disclosed in Japanese laid-open patent publication No. 7-63934, for example. The general technique of multiplexing and demultiplexing optical signals is disclosed in 10 Japanese laid-open patent publication No. 7-49430, for example.

With the conventional arrayed waveguide grating 11 shown in FIG. 1, the light emitted from channel waveguide array 15 into outlet slab waveguide 17 reaches output 20 waveguides 14 that is connected to the output side of outlet slab waveguide 17. In output waveguides 14, the intensity of the light is greater progressively toward the central ones of output waveguides 14, and smaller progressively toward the peripheral ones of output 25 waveguides 14.

Heretofore, it has been proposed to uniformize the levels of the optical signals thereby to uniform the levels of the optical signals that are detected from the output waveguides. According to one proposal, in order to adjust the levels of the optical signals that are detected from the output waveguides, attenuators for compensating loss differences are individually connected to the respective output waveguides, thus making up an attenuator. However, it is necessary to prepare as many resistors having different resistances as the number of the different levels of the optical signals that are detected from the output waveguides. Furthermore, since the attenuation levels of the attenuators vary depending on the temperature, it is necessary to use a temperature compensation circuit in combination with the attenuators. The arrayed waveguide grating with such attenuators for compensating loss differences is not practical as to cost and space.

An arrayed waveguide grating which is designed to extract a monitor signal using higher-order diffracted light tends to cause a large detected light level difference because a waveguide for guiding the monitor signal is positioned away from the optical axis of light emitted from a channel waveguide array. Consequently, the arrayed waveguide grating needs a structure for compensat-

ing for a signal level loss before or after the signal light is detected.

Japanese laid-open patent publication No. 2000-98177 discloses a device having an optical waveguide with a plurality of ports and an optical fiber array. Deviations between the ports and the propagation axes of the optical fibers of the optical fiber array are managed to set transmission losses between the ports of the optical waveguide to desired values. Though the disclosed arrangement does not need an external attenuator, it poses yield and cost problems because of the need for fine adjustment of the propagation axes.

While the drawbacks of the conventional arrayed waveguide gratings have been described above, multiplexers for multiplexing optical signals and demultiplexers for demultiplexing optical signals which employ the conventional arrayed waveguide gratings, and optical communication systems which employ the conventional arrayed waveguide gratings and the multiplexers and demultiplexers are also problematic in that they are complex in structure and large in size, and cannot be reduced in cost.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an arrayed waveguide grating which is capable of adjusting signal levels output from respective

5 waveguides without the need for circuit parts for compensating for loss differences and also the need for a process of highly accurately attaching parts, and a multiplexer, a demultiplexer, and an optical communication system which use such an arrayed waveguide grating.

According to a first aspect of the present invention, an arrayed waveguide grating comprises: one or plural input waveguides for inputting signal lights; a plurality of output waveguides for outputting signal lights; 10 a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences; an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides; and an output slab waveguide connecting an 15 output end of the channel waveguide array to the output waveguides, and having optical input/output characteristics set to predetermined ratios for the respective output waveguides with respect to the input waveguides.

The first aspect of the present invention is concerned with the demultiplexing of light, and optical input/output characteristics are set to predetermined ratios for the respective output waveguides with respect to the input waveguides. This makes it unnecessary to employ external circuit parts for compensating for loss 25 differences.

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According to a second aspect of the present invention, an arrayed waveguide grating comprises: one or plural input waveguides for inputting signal lights; a plurality of output waveguides for outputting signal lights;
5 a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences; an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides; and an output slab waveguide connecting an
10 output end of the channel waveguide array to the output waveguides, and having optical input/output characteristics set to predetermined ratios for the respective output waveguides with respect to the input waveguides depending on the differences between optical losses along
15 respective paths in the output slab waveguide.

The second aspect of the present invention is concerned with the demultiplexing of light, optical loss differences are developed at a boundary of the slab waveguide for thereby setting optical input/output characteristics predetermined ratios for the respective output waveguides with respect to the input waveguides.
20 This makes it unnecessary to employ external circuit parts for compensating for loss differences.

According to a third aspect of the present invention, an arrayed waveguide grating comprises: a plurality
25 of input waveguides for inputting signal lights having

different wavelengths each other; one or plural output waveguides for outputting signal lights; a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences;

5 an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides; and an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides, and having optical input/output characteristics set to predetermined

10 ratios for the respective input waveguides corresponding to the output waveguides.

Unlike the first aspect of the present invention, the third aspect of the present invention is concerned with the multiplexing of lights, and optical input/output

15 characteristics are set to predetermined ratios for the respective input waveguides with respect to the output waveguides. This makes it unnecessary to employ external circuit parts for compensating for loss differences.

According to a fourth aspect of the present invention,

20 tion, an arrayed waveguide grating comprises: a plurality of input waveguides for inputting signal lights having different wavelengths each other; one or plural output waveguides for outputting signal lights; a channel waveguide array having waveguides which are successively

25 longer with predetermined waveguide length differences; an output slab waveguide connecting an output end of the

channel waveguide array to the output waveguides; and an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides; and having optical input/output characteristics set to predetermined ratios for the respective input waveguides corresponding to the output waveguides depending on the differences between optical losses along respective paths in the output slab waveguide.

Unlike the second aspect of the present invention, the fourth aspect of the present invention is concerned with the multiplexing of lights, and optical loss differences are developed at boundaries of the input waveguides and the slab waveguide for thereby setting optical input/output characteristics predetermined ratios for the respective input waveguides with respect to the output waveguides. This makes it unnecessary to employ external circuit parts for compensating for loss differences.

According to a fifth aspect of the present invention, an arrayed waveguide grating comprises: one or plural input waveguides for inputting signal lights; a plurality of output waveguides for outputting signal lights; a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences; an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides; and an output slab waveguide connecting an

output end of the channel waveguide array to the output waveguides, the output slab waveguide having a core layer disposed therein for propagating light therethrough, the core layer being partly cut off in selected or all paths
5 therein which interconnect the channel waveguide array and the output waveguides, and a cladding layer disposed in cut regions of the core layer and on opposite sides of the core layer, the cut regions in the paths having cut lengths set to predetermined values in the direction in
10 which the signal lights propagate, depending on optical losses of the signal lights propagated in the paths.

With the fifth aspect of the present invention, the core layer of the slab waveguide is partly cut off as required, and the optical losses with respect to the output
15 waveguides at the time of demultiplexing the light signal are adjusted based on the lengths of the cut regions.

According to a sixth aspect of the present invention, an arrayed waveguide grating comprises: a plurality of input waveguides for inputting signal lights having
20 different wavelengths each other; one or plural output waveguides for outputting signal lights; a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences; an output slab waveguide connecting an output end of the
25 channel waveguide array to the output waveguides; and an input slab waveguide connecting an input end of the chan-

nel waveguide array to the input waveguides, the input
slab waveguide having a core layer disposed therein for
propagating light therethrough, the core layer being
partly cut off in selected or all paths therein which in-
5 terconnect the channel waveguide array and the input
waveguides, and a cladding layer disposed in cut regions
of the core layer and on opposite sides of the core
layer, the cut regions in the paths having cut lengths
set to predetermined values in the direction in which the
10 signal lights propagate, depending on optical losses of
the signal lights propagated in the paths.

With the sixth aspect of the present invention, the
core layer of the slab waveguide is partly cut off as re-
quired, and the optical losses of the signal lights to be
15 multiplexed into the output waveguides are adjusted based
on the lengths of the cut regions.

According to a seventh aspect of the present inven-
tion, an arrayed waveguide grating comprises: one or plu-
ral input waveguides for inputting signal lights; a plu-
20 rality of output waveguides for outputting signal lights;
the output waveguides having at least one core layer dis-
posed therein for propagating light therethrough, the
core layer being partly cut off, and a cladding layer
disposed in cut regions of the core layer and on opposite
25 sides of the core layer, the cut regions having cut
lengths set to predetermined values depending on optical

losses of the signal lights propagated in the output waveguides; a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences; an input slab waveguide
5 connecting an input end of the channel waveguide array to the input waveguides; and an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides.

With the seventh aspect of the present invention,
10 whereas the core layer of the slab waveguide is partly cut off as required with the fifth aspect of the present invention, the core layer of some or all of the output waveguides for propagating the signal lights output from the slab waveguide is partly cut off as required, and the
15 optical losses with respect to the output waveguides are adjusted based on the lengths of the cut regions.

According to an eighth aspect of the present invention, an arrayed waveguide grating comprises: a plurality of input waveguides for inputting signal lights having
20 different wavelengths each other, the input waveguides having at least one core layer disposed therein for propagating light therethrough, the core layer being partly cut off, and a cladding layer disposed in cut regions of the core layer and on opposite sides of the core
25 layer, the cut regions having cut lengths set to predetermined values depending on optical losses of the signal

lights propagated in the input waveguides; one or plural
output waveguides for outputting signal lights; a channel
waveguide array having waveguides which are successively
longer with predetermined waveguide length differences,
5 an input slab waveguide connecting an input end of the
channel waveguide array to the input waveguides; and an
output slab waveguide connecting an output end of the
channel waveguide array to the output waveguides.

With the eighth aspect of the present invention,
10 whereas the core layer of the slab waveguide is partly
cut off as required with the sixth aspect of the present
invention, the core layer of some or all of the input
waveguides for transmitting the signal lights into the
slab waveguide is partly cut off as required, and the op-
15 tical losses with respect to the input waveguides are ad-
justed based on the lengths of the cut regions.

According to a ninth aspect of the present inven-
tion, an arrayed waveguide grating comprises: one or plu-
ral input waveguides for inputting signal lights; a chan-
20 nel waveguide array having waveguides which are succes-
sively longer with predetermined waveguide length differ-
ences; an input slab waveguide connecting an input end of
the channel waveguide array to the input waveguides; an
output slab waveguide connecting an output end of the
25 channel waveguide array to the input end thereof; and a
plurality of output waveguides having respective ends

connected to the output end of the output slab waveguide,
wherein selected or all of the ends of the output
waveguides have respective central positions displaced
from corresponding focused positions in a direction per-
5 pendicular to central axes of the output waveguides by
predetermined values depending on losses to be given to
the signal lights propagated in the output waveguides.

Usually, the focused positions located in the vi-
cinity of the boundary of the slab waveguide at its out-
10 put end are aligned with the central axes of the output
waveguides to increase the coupling efficiency. With the
ninth aspect of the present invention, the central posi-
tions of the ends of the output waveguides which face the
slab waveguide are displaced from the corresponding fo-
15 cused positions in the direction perpendicular to the
central axes of the output waveguides by predetermined
values depending on losses to be given to the signal
lights propagated in the output waveguides, thereby ad-
justing the losses of the signal lights propagated in the
20 output waveguides.

According to a tenth aspect of the present inven-
tion, an arrayed waveguide grating comprises: a channel
waveguide array having waveguides which are successively
longer with predetermined waveguide length differences;
25 an input slab waveguide having an output end connected to
an input end of the channel waveguide array; one or plu-

5 ral output waveguides for outputting signal lights; an
output slab waveguide connecting an output end of the
channel waveguide array to the output waveguides; and a
plurality of input waveguides having respective ends con-
10 nected to the input end of the input slab waveguide,
wherein selected or all of the ends of the input
waveguides have respective central positions displaced
from corresponding focused positions in a direction per-
pendicular to central axes of the input waveguides by
15 predetermined values depending on losses to be given to
the signal lights propagated in the output waveguides.

Usually, the central axis of an output waveguide
for extracting a multiplexed signal is aligned with the
optical axe of the multiplexed signal coupled to the out-
15 put waveguide to increase the total efficiency. With the
tenth aspect of the present invention, the input
waveguides are displaced in the direction perpendicular
to the central axes thereof to shift the propagation axes
of the signal lights coupled to the output waveguides de-
20 pending on losses to be given to the signal lights propa-
gated in the output waveguides. The losses of the signal
lights propagated in the output waveguides are adjusted
based on the distances by which the input waveguides are
displaced.

25 According to an eleventh aspect of the present in-
vention, an arrayed waveguide grating comprises: a chan-

nel waveguide array having waveguides which are successively longer with predetermined waveguide length differences; an input slab waveguide having an output end connected to an input end of the channel waveguide array;

5 one or plural input waveguides for inputting signal lights, the input waveguides having output ends connected to an input end of the input slab waveguide; an output slab waveguide having an input end connected to an output end of the channel waveguide array; and a plurality of

10 output waveguides having respective ends connected to the output end of the output slab waveguide, wherein selected or all of central axes of the output waveguides are inclined at the interconnected points of the output waveguides and the channel waveguide array at respective

15 angles depending on losses to be given to the signal lights coupled at the interconnected points.

With the eleventh aspect of the present invention, the angles between the central axes of the output waveguides for extracting demultiplexed signal lights and

20 the propagation axes of the demultiplexed signal lights coupled to the respective output waveguides are set depending on losses to be given to the signal lights, for thereby adjusting the losses of the signal lights propagated in the output waveguides.

25 According to a twelfth aspect of the present invention, an arrayed waveguide grating comprises: a channel

5 waveguide array having waveguides which are successively longer with predetermined waveguide length differences; an input slab waveguide having an output end connected to an input end of the channel waveguide array; one or plural output waveguides for outputting signal lights; an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides; and a plurality of input waveguides having respective ends connected to the input end of the input slab waveguide, 10 wherein selected or all of central axes of the input waveguides are inclined at the interconnected points of the input waveguides and the input slab waveguide at respective angles depending on losses to be given to the signal lights coupled at the interconnected points.

15 With the twelfth aspect of the present invention, the angles between the ends of the input waveguides and the input slab waveguide array and the central axes of the input waveguides set depending on losses to be given to the signal lights, for thereby adjusting the losses of 20 the signal lights transmitted respectively from input waveguides.

According to a thirteenth aspect of the present invention, an arrayed waveguide grating comprises: a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences; an input slab waveguide having an output end con-

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lights; an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides; and a plurality of input waveguides having respective ends connected to the input end of the input slab

5 waveguide, wherein selected or all widths of the input waveguides at ends thereof are set to predetermined values depending on losses to be given to the signal lights.

With the fourteenth aspect of the present invention, the widths, in the direction perpendicular to the
10 propagation axes, of selected or all of the input waveguides at their portions connected to the input slab waveguide are set to values depending on losses to be given to the signal lights, for thereby adjusting the losses of the signal lights propagated in the input
15 waveguides.

According to a fifteenth aspect of the present invention, an arrayed waveguide grating comprises: a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences;
20 an input slab waveguide having an output end connected to an input end of the channel waveguide array; one or plural input waveguides for inputting signal lights, the input waveguides having output ends connected to an input end of the input slab waveguide; an output
25 slab waveguide having an input end connected to an output end of the channel waveguide array; and a plurality of

output waveguides having respective ends connected to the output end of the output slab waveguide wherein the ends of the output waveguides and the channel waveguide array are displaced in the direction of propagation axes of the output waveguides depending on losses to be given to the signal lights propagated from the channel waveguide array to the ends of the output waveguides.

Usually, the focused positions located in the vicinity of the boundary of the slab waveguide at its output end are aligned with the central axes of the output waveguides to increase the coupling efficiency to the output waveguides. With the fifteenth aspect of the present invention, the lengths between the ends of the output waveguides and the focused positions are displaced, for some or all of the output waveguides, in the direction of propagation axes of the output waveguides depending on losses to be given to the signal lights propagated to the output waveguides, for thereby adjusting the losses of the signal lights propagated in the output waveguides.

According to a sixteenth aspect of the present invention, an arrayed waveguide grating comprises: a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences; an input slab waveguide having an output end connected to an input end of the channel waveguide array;

one or plural output waveguides for outputting signal
lights; an output slab waveguide connecting an output end
of the channel waveguide array to the output waveguides;
and a plurality of input waveguides having respective
5 ends connected to the input end of the input slab
waveguide, wherein the lengths between the ends of the
input waveguides and the channel waveguide array are dis-
placed in the direction of propagation axes of the input
waveguides depending on losses to be given to the signal
10 lights propagated from the channel waveguide array to the
ends of the input waveguides.

Usually, the focused positions located in the vi-
cinity of the boundary of the output slab waveguide and
the ends of the output waveguides are aligned to increase
15 the coupling efficiency of the signal lights which are
propagated from the input waveguides through the channel
waveguide array to the output slab waveguide. With the
sixteenth aspect of the present invention, some or all of
the input waveguides are displaced from their normal po-
20 sitions in the direction of the propagation axes depend-
ing on losses to be given to the signal lights, for
thereby adjusting the losses of the signal lights.

According to a seventeenth aspect of the present
invention, a demultiplexer comprises: an arrayed
25 waveguide grating comprising one or plural input
waveguides for inputting signal lights; a plurality of

output waveguides for outputting signal lights; a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences; an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides; and an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and having optical input/output characteristics set to predetermined ratios for the respective output waveguides with respect to the input waveguides; and level adjusting means for being supplied with the signal lights of respective wavelengths from the output waveguides of the arrayed waveguide grating, and adjusting output levels of the signal lights to desired values.

With the seventeenth aspect of the present invention, the arrayed waveguide grating itself sets the optical input/output characteristics to predetermined ratios for the respective output waveguides with respect to the input waveguides, and the level adjusting means is supplied with the signal lights of respective wavelengths from the output waveguides and adjusts output levels of the signal lights to desired values. The input/output characteristics can thus be made flat or freely adjusted depending on an apparatus or system with which the demultiplexer is used.

According to an eighteenth aspect of the present invention, a demultiplexer comprises: an arrayed waveguide grating comprising one or plural input waveguides for inputting signal lights, a plurality of
5 output waveguides for outputting signal lights, a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences, an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides, and an
10 output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and having optical input/output characteristics set to predetermined ratios for the respective output waveguides with respect to the input waveguides depending on the differ-
15 ences between optical losses along respective paths in the output slab waveguide; and level adjusting means for being supplied with the signal lights of respective wavelengths from the output waveguides of the arrayed waveguide grating, and adjusting output levels of the
20 signal lights to desired values.

With the eighteenth aspect of the present invention, the arrayed waveguide grating itself sets the optical input/output characteristics to predetermined ratios for the respective output waveguides with respect to the
25 input waveguides based on optical loss differences at the boundary of the slab waveguide, and the level adjusting

means is supplied with the signal lights of respective wavelengths from the output waveguides and adjusts output levels of the signal lights to desired values. The input/output characteristics can thus be made flat or
5 freely adjusted depending on an apparatus or system with which the demultiplexer is used.

According to a nineteenth aspect of the present invention, a multiplexer comprises: a plurality of light sources; an arrayed waveguide grating comprising a plurality of input waveguides for inputting signal lights
10 having different wavelengths each other, one or plural output waveguides for outputting signal lights, a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences,
15 an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides, and having optical input/output characteristics set to predetermined
20 ratios for the respective input waveguides corresponding to the output waveguides; level detecting means for detecting levels of the signal lights input from the light sources to the arrayed waveguide grating; and level adjusting means for comparing the levels of the signal
25 lights detected by the level detecting means with predetermined levels for the respective wavelengths, and ad-

justing output levels of the light sources to set the levels of the waveguides multiplexed by the arrayed waveguide grating to desired values.

With the nineteenth aspect of the present invention, the arrayed waveguide grating itself sets the optical input/output characteristics to predetermined ratios for the respective input waveguides with respect to the output waveguides, and the levels of the signal lights input from the light sources to the arrayed waveguide grating are detected by the level detecting means. By adjusting the output levels of the light sources, the levels of the signal lights of the respective wavelengths which have been multiplexed by the arrayed waveguide grating are set to desired values. The input/output characteristics can thus be made flat or freely adjusted at the output waveguides depending on an apparatus or system with which the demultiplexer is used.

According to a twentieth aspect of the present invention, a multiplexer comprises: a plurality of light sources; an arrayed waveguide grating comprising a plurality of input waveguides for inputting signal lights having different wavelengths each other, one or plural output waveguides for outputting signal lights, a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences, an output slab waveguide connecting an output end of the

channel waveguide array to the output waveguides, and an
input slab waveguide connecting an input end of the chan-
nel waveguide array to the input waveguides, and having
optical input/output characteristics set to predetermined
5 ratios for the respective input waveguides corresponding
to the output waveguides depending on the differences be-
tween optical losses along respective paths in the output
slab waveguide; level detecting means for detecting lev-
els of the signal lights input from the light sources to
10 the arrayed waveguide grating; and level adjusting means
for comparing the levels of the signal lights detected by
the level detecting means with predetermined levels for
the respective wavelengths, and adjusting output levels
of the light sources to set the levels of the waveguides
15 multiplexed by the arrayed waveguide grating to desired
values.

With the twentieth aspect of the present invention,
the arrayed waveguide grating itself sets the optical in-
put/output characteristics to predetermined ratios for
20 the respective input waveguides with respect to the out-
put waveguides based on optical loss differences at the
boundary of the slab waveguide, and the levels of the
signal lights input from the light sources to the arrayed
waveguide grating are detected by the level detecting
25 means. By adjusting the output levels of the light
sources, the levels of the signal lights of the respec-

5 tive wavelengths which have been multiplexed by the arrayed waveguide grating are set to desired values. The input/output characteristics can thus be made flat or freely adjusted at the output waveguides depending on an apparatus or system with which the demultiplexer is used.

According to a twenty-first aspect of the present invention, an optical communication system comprises: optical transmitting means for transmitting optical signals of respective wavelengths parallel to each other; a multiplexer for wavelength-division multiplexing the optical signals of respective wavelengths transmitted by the light transmitting means; an optical transmission path for transmitting a wavelength-division multiplexed optical signal output from the multiplexer; a node disposed in the optical transmission path and having an arrayed waveguide grating; a demultiplexer for being supplied with the optical signal transmitted over the optical transmission path via the node and demultiplexing the optical signal into the optical signals of respective wavelengths; and optical receiving means for receiving the optical signals of respective wavelengths demultiplexed by the demultiplexer; the multiplexer comprising an arrayed waveguide grating comprising a plurality of input waveguides for inputting signal lights having different wavelengths each other, one or plural output waveguides for outputting signal lights, a channel waveguide array

having waveguides which are successively longer with predetermined waveguide length differences, an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and an input

5 slab waveguide connecting an input end of the channel waveguide array to the input waveguides, and having optical input/output characteristics set to predetermined ratios for the respective input waveguides corresponding to the output waveguides; the demultiplexer comprising an

10 arrayed waveguide grating comprising one or plural input waveguides for inputting signal lights, a plurality of output waveguides for outputting signal lights, a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences,

15 an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides, and an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and having optical input/output characteristics set to prede-

20 termined ratios for the respective output waveguides with respect to the input waveguides.

With the twenty-first aspect of the present invention, the optical communication system, which is of an linear type, comprises optical transmitting means, a mul-

25 tiplexer for wavelength-division multiplexing the optical signals of respective wavelengths transmitted by the

light transmitting means, an optical transmission path
for transmitting a multiplexed optical signal output from
the multiplexer, a node disposed in the optical transmis-
sion path and having an arrayed waveguide grating, a de-
5 multiplexer for being supplied with the optical signal
transmitted over the optical transmission path via the
node and demultiplexing the optical signal into the opti-
cal signals of respective wavelengths, and optical re-
ceiving means for receiving the optical signals of re-
10 spective wavelengths demultiplexed by the demultiplexer.
The multiplexer comprises an arrayed waveguide grating
according to the third aspect and sets optical in-
put/output characteristics to predetermined ratios for
the respective input waveguides corresponding to the out-
15 put waveguides, and the demultiplexer comprises an ar-
rayed waveguide grating according to the first aspect and
sets optical input/output characteristics to predeter-
mined ratios for the respective output waveguides with
respect to the input waveguides.

20 According to a twenty-second aspect of the present
invention, an optical communication system comprises: op-
tical transmitting means for transmitting optical signals
of respective wavelengths parallel to each other; a mul-
tiplexer for wavelength-division multiplexing the optical
25 signals of respective wavelengths transmitted by the
light transmitting means; an optical transmission path

for transmitting a wavelength-division multiplexed optical signal output from the multiplexer, a node disposed in the optical transmission path and having an arrayed waveguide grating; a demultiplexer for being supplied
5 with the optical signal transmitted over the optical transmission path via the node and demultiplexing the optical signal into the optical signals of respective wavelengths; and optical receiving means for receiving the optical signals of respective wavelengths demultiplexed
10 by the demultiplexer; the multiplexer comprising an arrayed waveguide grating comprising a plurality of input waveguides for inputting signal lights having different wavelengths each other, one or plural output waveguides for outputting signal lights, a channel waveguide array
15 having waveguides which are successively longer with predetermined waveguide length differences, an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and an input slab waveguide connecting an input end of the channel
20 waveguide array to the input waveguides, and having optical input/output characteristics set to predetermined ratios for the respective input waveguides corresponding to the output waveguides depending on the differences between optical losses along respective paths in the output
25 slab waveguide; the demultiplexer comprising an arrayed waveguide grating comprising one or plural input

waveguides for inputting signal lights, a plurality of
output waveguides for outputting signal lights, a channel
waveguide array having waveguides which are successively
longer with predetermined waveguide length differences,
5 an input slab waveguide connecting an input end of the
channel waveguide array to the input waveguides, and an
output slab waveguide connecting an output end of the
channel waveguide array to the output waveguides, and
having optical input/output characteristics set to prede-
10 termined ratios for the respective output waveguides with
respect to the input waveguides depending on the differ-
ences between optical losses along respective paths in
the output slab waveguide.

With the twenty-second aspect of the present inven-
15 tion, the optical communication system, which is of an
linear type, comprises optical transmitting means, a mul-
tiplexer for wavelength-division multiplexing the optical
signals of respective wavelengths transmitted by the
light transmitting means, an optical transmission path
20 for transmitting a multiplexed optical signal output from
the multiplexer, a node disposed in the optical transmis-
sion path and having an arrayed waveguide grating, a de-
multiplexer for being supplied with the optical signal
transmitted over the optical transmission path via the
25 node and demultiplexing the optical signal into the opti-
cal signals of respective wavelengths, and optical re-

ceiving means for receiving the optical signals of respective wavelengths demultiplexed by the demultiplexer. The multiplexer comprises an arrayed waveguide grating according to the fourth aspect and sets optical input/output characteristics to predetermined ratios for the respective input waveguides corresponding to the output waveguides, and the demultiplexer comprises an arrayed waveguide grating according to the second aspect and sets optical input/output characteristics to predetermined ratios for the respective output waveguides with respect to the input waveguides.

According to a twenty-third aspect of the present invention, an optical communication system comprises: an annular transmission path having a plurality of nodes interconnected in a ring by a transmission path, for transmitting a multiplexed optical signal over the transmission path; each of the nodes having a first arrayed waveguide grating for demultiplexing a multiplexed optical signal into optical signals of respective wavelengths, and a second arrayed waveguide grating for multiplexing the demultiplexed optical signals of respective wavelengths; the first arrayed waveguide grating comprising one or plural input waveguides for inputting signal lights, a plurality of output waveguides for outputting signal lights, a channel waveguide array having waveguides which are successively longer with predeter-

mined waveguide length differences, an input slab
waveguide connecting an input end of the channel
waveguide array to the input waveguides, and an output
slab waveguide connecting an output end of the channel
5 waveguide array to the output waveguides, and having op-
tical input/output characteristics set to predetermined
ratios for the respective output waveguides with respect
to the input waveguides; the second arrayed waveguide
grating comprising a plurality of input waveguides for
10 inputting signal lights having different wavelengths each
other, one or plural output waveguides for outputting
signal lights, a channel waveguide array having
waveguides which are successively longer with predeter-
mined waveguide length differences, an output slab
15 waveguide connecting an output end of the channel
waveguide array to the output waveguides, and an input
slab waveguide connecting an input end of the channel
waveguide array to the input waveguides, and having opti-
cal input/output characteristics set to predetermined ra-
20 tios for the respective input waveguides corresponding to
the output waveguides.

With the twenty-third aspect of the present inven-
tion, the optical communication system, which is of an
annular type, comprises an annular transmission path hav-
25 ing a plurality of nodes interconnected in a ring by a
transmission path, for transmitting a multiplexed optical

signal over the transmission path, each of the nodes having a first arrayed waveguide grating for demultiplexing a multiplexed optical signal into optical signals of respective wavelengths, and a second arrayed waveguide
5 grating for multiplexing the demultiplexed optical signals of respective wavelengths. The first arrayed waveguide grating comprises an arrayed waveguide grating according to the third aspect and sets optical input/output characteristics to predetermined ratios for
10 the respective output waveguides connected to the output end of the slab waveguide with respect to the input waveguides. The second arrayed waveguide grating comprises an arrayed waveguide grating according to the first aspect and sets optical input/output characteristics
15 to predetermined ratios for the respective input waveguides corresponding to the output waveguides.

According to a twenty-fourth aspect of the present invention, an optical communication system comprises: an annular transmission path having a plurality of nodes interconnected in a ring by a transmission path, for transmitting a multiplexed optical signal over the transmission path; each of the nodes having a first arrayed
20 waveguide grating for demultiplexing a multiplexed optical signal into optical signals of respective wavelengths, and a second arrayed waveguide grating for multiplexing the demultiplexed optical signals of respective
25

5 wavelengths; the first arrayed waveguide grating comprising one or plural input waveguides for inputting signal lights, a plurality of output waveguides for outputting signal lights, a channel waveguide array having

10 waveguides which are successively longer with predetermined waveguide length differences, an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides, and an output slab waveguide connecting an output end of the channel

15 waveguide array to the output waveguides, and having optical input/output characteristics set to predetermined ratios for the respective output waveguides with respect to the input waveguides depending on the differences between optical losses along respective paths in the output

20 slab waveguide; the second arrayed waveguide grating comprising a plurality of input waveguides for inputting signal lights having different wavelengths each other, one or plural output waveguides for outputting signal lights, a channel waveguide array having waveguides which

25 are successively longer with predetermined waveguide length differences, an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and an input slab waveguide connecting an input end of the channel waveguide array to the input

waveguides, and having optical input/output characteristics set to predetermined ratios for the respective input

waveguides corresponding to the output waveguides depending on the differences between optical losses along respective paths in the output slab waveguide.

With the twenty-fourth aspect of the present invention, the optical communication system, which is of an annular type, comprises an annular transmission path having a plurality of nodes interconnected in a ring by a transmission path, for transmitting a wavelength-division multiplexed optical signal over the transmission path, each of the nodes having a first arrayed waveguide grating for demultiplexing a wavelength-division multiplexed optical signal into optical signals of respective wavelengths, and a second arrayed waveguide grating for wavelength-division multiplexing the demultiplexed optical signals of respective wavelengths. The first arrayed waveguide grating comprises an arrayed waveguide grating according to the fourth aspect and sets optical input/output characteristics to predetermined ratios for the respective output waveguides connected to the output end of the slab waveguide with respect to the input waveguides. The second arrayed waveguide grating comprises an arrayed waveguide grating according to the second aspect and sets optical input/output characteristics to predetermined ratios for the respective input waveguides corresponding to the output waveguides.

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According to a twenty-fifth aspect of the present invention, an optical communication system comprises: optical transmitting means for transmitting optical signals of respective wavelengths parallel to each other; a multiplexer for multiplexing the optical signals of respective wavelengths transmitted by the light transmitting means; an optical transmission path for transmitting a multiplexed optical signal output from the multiplexer; a node disposed in the optical transmission path; a demultiplexer for being supplied with the optical signal transmitted over the optical transmission path via the node and demultiplexing the optical signal into the optical signals of respective wavelengths; and optical receiving means for receiving the optical signals of respective wavelengths demultiplexed by the demultiplexer; the multiplexer comprising an arrayed waveguide grating having a plurality of input waveguides for inputting signal lights having different wavelengths each other, one or plural output waveguides for outputting signal lights, a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences, an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides, and having optical input/output characteris-

tics set to predetermined ratios for the respective input waveguides corresponding to the output waveguides, level detecting means for detecting levels of the signal lights input to the arrayed waveguide grating, and level adjusting means for comparing the levels of the signal lights detected by the level detecting means with predetermined levels for the respective wavelengths, and adjusting output levels of the light signals to set the levels of the waveguides multiplexed by the arrayed waveguide grating to desired values; the demultiplexer comprising an arrayed waveguide grating comprising one or plural input waveguides for inputting signal lights, a plurality of output waveguides for outputting signal lights, a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences, an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides, and an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and having optical input/output characteristics set to predetermined ratios for the respective output waveguides with respect to the input waveguides, and level adjusting means for being supplied with the signal lights of respective wavelengths from the output waveguides of the arrayed waveguide grating, and adjusting output levels of the signal lights to desired values.

With the twenty-fifth aspect of the present invention, the optical communication system, which is of a linear type, comprises optical transmitting means, a multiplexer for wavelength-division multiplexing the optical signals of respective wavelengths transmitted by the light transmitting means, an optical transmission path for transmitting a wavelength-division multiplexed optical signal output from the multiplexer, a node disposed in the optical transmission path, a demultiplexer for being supplied with the optical signal transmitted over the optical transmission path via the node and demultiplexing the optical signal into the optical signals of respective wavelengths, and optical receiving means for receiving the optical signals of respective wavelengths demultiplexed by the demultiplexer. The multiplexer comprises a device according to the nineteenth aspect, and the demultiplexer comprises a device according to the seventeenth aspect, thus setting optical input/output characteristics to predetermined ratios.

According to a twenty-sixth aspect of the present invention, an optical communication system comprises: optical transmitting means for transmitting optical signals of respective wavelengths parallel to each other; a multiplexer for multiplexing the optical signals of respective wavelengths transmitted by the light transmitting means; an optical transmission path for transmitting a

5 multiplexed optical signal output from the multiplexer; a
node disposed in the optical transmission path, a demul-
tiplexer for being supplied with the optical signal
transmitted over the optical transmission path via the
10 node and demultiplexing the optical signal into the opti-
cal signals of respective wavelengths; and optical re-
ceiving means for receiving the optical signals of re-
spective wavelengths demultiplexed by the demultiplexer;
the multiplexer comprising an arrayed waveguide grating
15 comprising a plurality of input waveguides for inputting
signal lights having different wavelengths each other,
one or plural output waveguides for outputting signal
lights, a channel waveguide array having waveguides which
are successively longer with predetermined waveguide
20 length differences, an output slab waveguide connecting
an output end of the channel waveguide array to the out-
put waveguides, and an input slab waveguide connecting an
input end of the channel waveguide array to the input
waveguides, and having optical input/output characteris-
25 tics set to predetermined ratios for the respective input
waveguides corresponding to the output waveguides depend-
ing on the differences between optical losses along re-
spective paths in the output slab waveguide, level de-
tecting means for detecting levels of the signal lights
input to the arrayed waveguide grating, and level adjust-
ing means for comparing the levels of the signal lights

detected by the level detecting means with predetermined levels for the respective wavelengths, and adjusting output levels of the signal lights to set the levels of the waveguides multiplexed by the arrayed waveguide grating to desired values; the demultiplexer comprising an arrayed waveguide grating comprising one or plural input waveguides for inputting signal lights, a plurality of output waveguides for outputting signal lights, a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences, an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides, and an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and having optical input/output characteristics set to predetermined ratios for the respective output waveguides with respect to the input waveguides depending on the differences between optical losses along respective paths in the output slab waveguide, and level adjusting means for being supplied with the signal lights of respective wavelengths from the output waveguides of the arrayed waveguide grating, and adjusting output levels of the signal lights to desired values.

With the twenty-sixth aspect of the present invention, the optical communication system, which is of a linear type, comprises optical transmitting means, a mul-

triplexer for wavelength-division multiplexing the optical signals of respective wavelengths transmitted by the light transmitting means, an optical transmission path for transmitting a wavelength-division multiplexed optical signal output from the multiplexer, a node disposed in the optical transmission path, a demultiplexer for being supplied with the optical signal transmitted over the optical transmission path via the node and demultiplexing the optical signal into the optical signals of respective wavelengths, and optical receiving means for receiving the optical signals of respective wavelengths demultiplexed by the demultiplexer. The multiplexer comprises a device according to the twentieth aspect, and the demultiplexer comprises a device according to the eighteenth aspect, thus setting optical input/output characteristics to predetermined ratios.

According to a twenty-seventh aspect of the present invention, an optical communication system comprises: an annular transmission path having a plurality of nodes interconnected in a ring by a transmission path, for transmitting a multiplexed optical signal over the transmission path; each of the nodes having a demultiplexer for demultiplexing a multiplexed optical signal into optical signals of respective wavelengths, and a multiplexer for multiplexing the demultiplexed optical signals of respective wavelengths; the demultiplexer comprising an arrayed

waveguide grating comprising one or plural input waveguides for inputting signal lights, a plurality of output waveguides for outputting signal lights, a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences, an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides, and an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and having optical input/output characteristics set to predetermined ratios for the respective output waveguides with respect to the input waveguides, and level adjusting means for being supplied with the signal lights of respective wavelengths from the output waveguides of the arrayed waveguide grating, and adjusting output levels of the signal lights to desired values; the multiplexer comprising an arrayed waveguide grating having a plurality of input waveguides for inputting signal lights having different wavelengths each other, one or plural output waveguides for outputting signal lights, a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences, an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides, and having

optical input/output characteristics set to predetermined ratios for the respective input waveguides corresponding to the output waveguides, level detecting means for detecting levels of the signal lights input to the arrayed waveguide grating, and level adjusting means for comparing the levels of the signal lights detected by the level detecting means with predetermined levels for the respective wavelengths, and adjusting output levels of the light signals to set the levels of the waveguides multiplexed by the arrayed waveguide grating to desired values.

With the twenty-seventh aspect of the present invention, the optical communication system, which is of an annular type, comprises an annular transmission path having a plurality of nodes interconnected in a ring by a transmission path, for transmitting a wavelength-division multiplexed optical signal over the transmission path, each of the nodes having a demultiplexer for demultiplexing a wavelength-division multiplexed optical signal into optical signals of respective wavelengths, and a multiplexer for multiplexing the demultiplexed optical signals of respective wavelengths. The demultiplexer comprises: a device according to the seventeenth aspect, and the demultiplexer comprises a device according to the nineteenth aspect, thus setting optical input/output characteristics to predetermined ratios.

According to a twenty-eighth aspect of the present invention, an optical communication system comprises: an annular transmission path having a plurality of nodes interconnected in a ring by a transmission path, for transmitting a multiplexed optical signal over the transmission path; each of the nodes having a demultiplexer for demultiplexing a multiplexed optical signal into optical signals of respective wavelengths, and a multiplexer for multiplexing the demultiplexed optical signals of respective wavelengths; the demultiplexer comprising an arrayed waveguide grating comprising one or plural input waveguides for inputting signal lights, a plurality of output waveguides for outputting signal lights, a channel waveguide array having waveguides which are successively longer with predetermined waveguide length differences, an input slab waveguide connecting an input end of the channel waveguide array to the input waveguides, and an output slab waveguide connecting an output end of the channel waveguide array to the output waveguides, and having optical input/output characteristics set to predetermined ratios for the respective output waveguides with respect to the input waveguides depending on the differences between optical losses along respective paths in the output slab waveguide, and level adjusting means for being supplied with the signal lights of respective wavelengths from the output waveguides of the arrayed

5 waveguide grating, and adjusting output levels of the
signal lights to desired values; the multiplexer compris-
ing an arrayed waveguide grating comprising a plurality
of input waveguides for inputting signal lights having
different wavelengths each other, one or plural output
waveguides for outputting signal lights, a channel
waveguide array having waveguides which are successively
longer with predetermined waveguide length differences,
an output slab waveguide connecting an output end of the
10 channel waveguide array to the output waveguides, and an
input slab waveguide connecting an input end of the chan-
nel waveguide array to the input waveguides, and having
optical input/output characteristics set to predetermined
ratios for the respective input waveguides corresponding
15 to the output waveguides depending on the differences be-
tween optical losses along respective paths in the output
slab waveguide, level detecting means for detecting lev-
els of the signal lights input to the arrayed waveguide
grating, and level adjusting means for comparing the lev-
20 els of the signal lights detected by the level detecting
means with predetermined levels for the respective wave-
lengths, and adjusting output levels of the signal lights
to set the levels of the waveguides multiplexed by the
arrayed waveguide grating to desired values.

25 With the twenty-eighth aspect of the present inven-
tion, the optical communication system, which is of an

annular type, comprises an annular transmission path having a plurality of nodes interconnected in a ring by a transmission path, for transmitting a multiplexed optical signal over the transmission path, each of the nodes having a demultiplexer for demultiplexing a wavelength-division multiplexed optical signal into optical signals of respective wavelengths, and a multiplexer for wavelength-division multiplexing the demultiplexed optical signals of respective wavelengths. The demultiplexer comprises a device according to the eighteenth aspect, and the demultiplexer comprises a device according to the twentieth aspect, thus setting optical input/output characteristics to predetermined ratios.

According to the twenty-first through twenty-eighth aspects of the present invention, input/output characteristics can be changed or output characteristics can be made flat without the need for attenuators, amplifiers, or signal level adjusting means outside of the waveguide device. Therefore, the overall system can be simplified, made highly reliable, and reduced in cost.

According to a twenty-ninth aspect of the present invention, a waveguide device comprises one or plural input waveguides for inputting signal lights, a plurality of output waveguides for outputting signal lights, and a slab waveguide having optical input/output characteris-

tics set to predetermined ratios for the respective output waveguides with respect to the input waveguides.

The twenty-ninth aspect of the present invention is concerned with the demultiplexing of light, and optical input/output characteristics are set to predetermined ratios for the respective output waveguides with respect to the input waveguides. This makes it unnecessary to employ external circuit parts for compensating for loss differences.

With the twenty-ninth and subsequent aspects of the present invention, unlike the twenty-eighth and former aspects of the present invention, the waveguide device does not have a channel waveguide, an input slab waveguide, or an output waveguide as an indispensable

component. With the twenty-eighth and former aspects of the present invention, the input waveguide is disposed on the input side of the input slab waveguide, and the output waveguide is disposed on the output side of the output slab waveguide. With the twenty-ninth and subsequent

aspects of the present invention, a device present on the input side of one slab waveguide is referred to as an input waveguide, and a device present on the output side of the slab waveguide is referred to as an output waveguide.

The slab waveguide referred to in the twenty-ninth and

subsequent aspects of the present invention may be regarded as an input slab waveguide of an arrayed waveguide

grating or an output slab waveguide of an arrayed waveguide grating. In other applications, e.g., in a single- or multi-stage star coupler, one or more waveguide devices can be used in combination. The

5 waveguide device may be used in other applications than the arrayed waveguide device and the star coupler.

If the slab waveguide referred to in the twenty-ninth and subsequent aspects of the present invention corresponds to an input waveguide, then the input

10 waveguide is the same as the input waveguide referred to in the twenty-eighth and former aspects of the present invention, but the output waveguide may correspond to individual waveguides of the channel waveguide array as the output waveguide is the waveguide on the output side.

15 Similarly, if the slab waveguide referred to in the twenty-ninth and subsequent aspects of the present invention corresponds to an output waveguide, then the output waveguide is the same as the output waveguide referred to in the twenty-eighth and former aspects of the present

20 invention, but the input waveguide may correspond to individual waveguides of the channel waveguide array as the input waveguide is the waveguide on the input side.

According to a thirtieth aspect of the present invention, a waveguide device comprises: a plurality of

25 output waveguides for outputting signal lights; one or plural input waveguides for inputting signal lights; and

a slab waveguide having optical input/output characteristics set to predetermined ratios for the respective input waveguides with respect to the output waveguides.

Unlike the twenty-ninth aspect of the present invention, the thirtieth aspect of the present invention is concerned with the multiplexing of lights, and optical input/output characteristics are set to predetermined ratios for the respective input waveguides with respect to the output waveguides. This makes it unnecessary to employ external circuit parts for compensating for loss differences.

According to a thirty-first aspect of the present invention, a waveguide device comprises: one or plural input waveguides for inputting signal lights; a plurality of output waveguides for outputting signal lights; and a slab waveguide connecting the input waveguides to the output waveguides, the slab waveguide having a core layer disposed therein for propagating light therethrough from the input waveguides to the output waveguides, the core layer being partly cut off in selected or all paths therein which interconnect the input waveguides and the output waveguides, and a cladding layer disposed in cut regions of the core layer and on opposite sides of the core layer, the cut regions in the paths having cut lengths set to predetermined values in the direction in

which the signal lights propagate, depending on optical losses of the signal lights propagated in the paths.

With the thirty-first aspect of the present invention, the core layer of the slab waveguide is partly cut
5 off as required, and the optical losses with respect to the output waveguides at the time of demultiplexing the light signal are adjusted based on the lengths of the cut regions.

According to a thirty-second aspect of the present
10 invention, a waveguide device comprises: a plurality of output waveguides for outputting signal lights; one or plural input waveguides for inputting signal lights; and a slab waveguide connecting the input waveguides to the output waveguides, the slab waveguide having a core layer
15 disposed therein for propagating light therethrough from the input waveguides to the output waveguides, the core layer being partly cut off in selected or all paths therein which interconnect the input waveguides and the output waveguides, and a cladding layer disposed in cut
20 regions of the core layer and on opposite sides of the core layer, the cut regions in the paths having cut lengths set to predetermined values in the direction in which the signal lights propagate, depending on optical losses of the signal lights propagated in the paths.

25 With the thirty-second aspect of the present invention, the core layer of the slab waveguide is partly cut

off as required, and the optical losses of the signal lights to be multiplexed into the output waveguides at the time of demultiplexing the light signal are adjusted based on the lengths of the cut regions.

5 According to a thirty-third aspect of the present invention, a waveguide device comprises: one or plural input waveguides for inputting signal lights; a slab waveguide having an input end connected to the input waveguides; and an output waveguide having a plurality of
10 waveguides connected to an output end of the slab waveguide, wherein each of selected or all of the waveguides have a core layer disposed therein for propagating light therethrough, the core layer being partly cut off, and a cladding layer disposed in cut regions of
15 the core layer and on opposite sides of the core layer, the cut regions having cut lengths set to predetermined values depending on optical losses of the signal lights propagated in the waveguides.

With thirty-third aspect of the present invention,
20 whereas the core layer of the slab waveguide is partly cut off as required with the thirty-first aspect of the present invention, the core layer of some or all of the output waveguides for propagating the signal lights output from the slab waveguide is partly cut off as re-
25 quired, and the optical losses with respect to the output

waveguides are adjusted based on the lengths of the cut regions.

According to a thirty-fourth aspect of the present invention, a waveguide device comprises: an input

5 waveguide having a plurality of waveguides for inputting signal lights, wherein each of selected or all of the waveguides have a core layer disposed therein for propagating light therethrough, the core layer being partly cut off, and a cladding layer disposed in cut regions of

10 the core layer and on opposite sides of the core layer, the cut regions having cut lengths set to predetermined values depending on optical losses of the signal lights propagated in the waveguides; one or plural output waveguides for outputting signal lights; and a slab

15 waveguide interconnecting the input waveguides and the output waveguides.

With the thirty-fourth aspect of the present invention, whereas the core layer of the slab waveguide is partly cut off as required with the thirty-second aspect

20 of the present invention, the core layer of some or all of the input waveguides for transmitting the signal lights into the slab waveguide is partly cut off as required, and the optical losses with respect to the input waveguides are adjusted based on the lengths of the cut

25 regions.

According to a thirty-fifth aspect of the present invention, a waveguide device comprises: one or plural input waveguides for inputting signal lights; a slab waveguide having an input end connected to output ends of the input waveguides; and an output waveguide having a plurality of waveguides connected to an output end of the slab waveguide, wherein selected or all of the waveguides have ends having respective central positions displaced from corresponding focused positions in a direction perpendicular to central axes of the waveguides by predetermined values depending on losses to be given to the signal lights propagated in the waveguides.

Usually, the focused positions located in the vicinity of the boundary of the slab waveguide at its output end are aligned with the central axes of the output waveguides to increase the coupling efficiency. With the thirty-fifth aspect of the present invention, the central positions of the ends of the output waveguides which face the slab waveguide are displaced from the corresponding focused positions in the direction perpendicular to the central axes of the output waveguides by predetermined values depending on losses to be given to the signal lights propagated in the output waveguides, thereby adjusting the losses of the signal lights propagated in the output waveguides.

According to a thirty-sixth aspect of the present invention, a waveguide device comprises: a slab waveguide; an output waveguide connected to an output end of the slab waveguide; and a plurality of input

5 waveguides having respective ends connected to an input end of the slab waveguide, wherein selected or all of the ends have respective central positions displaced from corresponding focused positions in a direction perpendicular to central axes of the input waveguides by prede-

10 termined values depending on losses to be given to the signal lights propagated in the output waveguides.

Usually, a plurality of light emission points on a slab waveguide are aligned with the central axes of input waveguides are aligned to increase the coupling effi-

15 ciency. With the thirty-sixth aspect of the present invention, distances by which the input waveguides are displaced in the direction perpendicular to the central axes thereof from the light emission points which are cophasal from the focused positions are set depending on losses to

20 be given to the signal lights propagated in the output waveguides. The losses of the signal lights propagated in the output waveguides are adjusted based on the distances by which the input waveguides are displaced.

According to a thirty-seventh aspect of the present invention, a waveguide device comprises: one or plural

25 input waveguides for inputting signal lights; a slab

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waveguide having an input end connected to output ends of the input waveguides; and a plurality of output waveguides having respective ends connected to an output end of the slab waveguide, wherein selected or all of central axes of the output waveguides are inclined at the interconnected points of the output waveguides and the slab waveguides at respective angles depending on losses to be given to the signal lights coupled at the interconnected points.

10 With the thirty-seventh aspect of the present invention, the angles between the light emission points on the input waveguides and the slab waveguides and the central axes of the output waveguides are set depending on losses to be given to the signal lights, for thereby adjusting the losses of the signal lights coupled with the output waveguides.

20 According to a thirty-eighth aspect of the present invention, a waveguide device comprises: one or plural output waveguides for outputting signal lights; a slab waveguide having an output end connected to input ends of the output waveguides; and a plurality of input waveguides having respective ends connected to an input end of the slab waveguide, wherein selected or all of central axes of the input waveguides are inclined at the interconnected points of the input waveguides and the slab waveguides at respective angles depending on losses

25

to be given to the signal coupled at the interconnected points.

With the thirty-eighth aspect of the present invention, the angles between the light emission points on the slab waveguides and the output waveguides and the central axes of the input waveguides are set depending on losses to be given to the signal lights, for thereby adjusting the losses of the signal lights in the input waveguides when the signal lights are transmitted from the input waveguides to the slab waveguide.

According to a thirty-ninth aspect of the present invention, a waveguide device comprises: one or plural input waveguides for inputting signal lights; a slab waveguide having an input end connected to output ends of the input waveguides; and a plurality of output waveguides having respective ends connected to an output end of the slab waveguide, wherein selected or all of the ends have waveguide widths set to values depending on losses to be given to the signal lights.

With the thirty-ninth aspect of the present invention, the widths, in the direction perpendicular to the propagation axes, of selected or all of the output waveguides are set to values depending on losses to be given to the signal lights, for thereby adjusting the losses of the signal lights propagated in the output waveguides.

According to a fortieth aspect of the present invention, a waveguide device comprises: one or plural output waveguides for outputting signal lights; a slab waveguide having an output end connected to input ends of the output waveguides; and a plurality of input waveguides having respective ends connected to an input end of the slab waveguide, wherein selected or all of the ends have waveguide widths set to values depending on losses to be given to the signal lights.

With the fortieth aspect of the present invention, the widths, in the direction perpendicular to the propagation axes, of selected or all of the input waveguides at their ends connected to the input slab waveguide are set to values depending on losses to be given to the signal lights, for thereby adjusting the losses of the signal lights propagated in the input waveguides.

According to a forty-first aspect of the present invention, a waveguide device comprises: one or plural input waveguides for inputting signal lights; a slab waveguide having an input end connected to output ends of the input waveguides; and a plurality of output waveguides having respective ends connected to an output end of the slab waveguide, wherein the lengths between the ends of the output waveguides and the input waveguides are displaced in the direction of propagation axes of the output waveguides depending on losses to be

given to the signal lights propagated from the input waveguides to the ends of the output waveguides.

Usually, the focused positions located in the vicinity of the boundary of the slab waveguide at its output end are aligned with the ends of the output waveguides to provide a focused state to increase the coupling efficiency to the output waveguides. With the forty-first aspect of the present invention, the lengths between the ends of the output waveguides and the focused positions are displaced, for some or all of the output waveguides, in the direction of propagation axes of the output waveguides depending on losses to be given to the signal lights propagated to the output waveguides, for thereby adjusting the losses of the signal lights propagated in the output waveguides.

According to a forty-second aspect of the present invention, a waveguide device comprises: one or plural output waveguides for outputting signal lights; a slab waveguide having an output end connected to input ends of the output waveguides; and a plurality of input waveguides having respective ends connected to an input end of the slab waveguide, wherein the lengths between the ends of the output waveguides and the input waveguides are displaced in the direction of propagation axes of the output waveguides depending on losses to be

given to the signal lights propagated from the output waveguides to the ends of the input waveguides.

Usually, a plurality of light emission points which are cophasal with focused positions located in the vicinity of the boundary of the slab waveguide at its output end are aligned with the ends of the input waveguides to increase the coupling efficiency of signal lights from the input waveguides coupled to the output waveguides. With the forty-second aspect of the present invention, some or all of the input waveguides are displaced from their normal positions in the direction of the propagation axes depending on losses to be given to the signal lights propagated in the input waveguides over the distances from the ends of the input waveguides to the focused positions, for thereby adjusting the losses of the signal lights.

With the twenty-ninth through forty-second aspects of the present invention, since the losses of the signal lights in the respective waveguides in the waveguide device are different from each other, input/output characteristics can be changed or output characteristics can be made flat without the need for attenuators, amplifiers, or signal level adjusting means outside of the waveguide device. Therefore, a module or a device using an arrayed waveguide grating can be simplified, made highly reliable, and reduced in cost.

According to a forty-third aspect of the present invention, a demultiplexer comprises: a waveguide device having one or plural input waveguides for inputting signal lights, a plurality of output waveguides for outputting signal lights, and a slab waveguide having optical input/output characteristics set to predetermined ratios for the respective output waveguides with respect to the input waveguides; and level adjusting means for being supplied with signal lights output from the output waveguides of the waveguide device, and adjusting output levels of the signal lights to desired values.

With the forty-third aspect of the present invention, the waveguide device itself sets the optical input/output characteristics to predetermined ratios for the respective output waveguides with respect to the input waveguides depending on optical loss differences at the boundary of the slab waveguide, and the level adjusting means is supplied with the signal lights of respective wavelengths from the output waveguides and adjusts output levels of the signal lights to desired values. The input/output characteristics can thus be made flat or freely adjusted. Furthermore, since the demultiplexer comprises the waveguide device with the input/output characteristics adjusted and the level adjusting means for adjusting the output levels of the wavelengths output from the output waveguides, errors of the input/output

characteristics of the waveguide device itself can be corrected.

According to a forty-fourth aspect of the present invention, a multiplexer comprises: a plurality of light
5 sources for respective signals; a waveguide device having a plurality of input waveguides for inputting signal lights, one or plural output waveguides for outputting signal lights, and a slab waveguide having optical input/output characteristics set to predetermined ratios
10 for the respective input waveguides with respect to the output waveguides; level detecting means for detecting levels of the signal lights input from the light sources to the waveguide device, and level adjusting means for comparing the levels of the signal lights detected by the
15 level detecting means with predetermined levels for the respective signal lights; and adjusting output levels of the respective signal lights to set the levels of the signal lights multiplexed by the waveguide device to desired values.

20 With the forty-fourth aspect of the present invention, the waveguide device itself sets the optical input/output characteristics to predetermined ratios for the respective input waveguides with respect to the output waveguides depending on optical loss differences at
25 the boundary of the slab waveguide, and the levels of the signal lights input from the light sources to the

waveguide device are detected by the level detecting means. By adjusting the output levels of the light sources, the levels of the signal lights of the respective wavelengths which have been multiplexed by the waveguide device are set to desired values. The input/output characteristics can thus be made flat or freely adjusted at the output waveguides. Furthermore, errors of the input/output characteristics of the waveguide device itself can be corrected.

- 10 According to a forty-fifth aspect of the present invention, an optical communication system comprises: optical transmitting means for transmitting optical signals of respective wavelengths parallel to each other; a multiplexer for multiplexing the optical signals of respective wavelengths transmitted by the light transmitting means; an optical transmission path for transmitting a multiplexed optical signal output from the multiplexer; a node disposed in the optical transmission path and having a waveguide device; a demultiplexer for being supplied with the optical signal transmitted over the optical transmission path via the node and demultiplexing the optical signal into the optical signals of respective wavelengths; and optical receiving means for receiving the optical signals of respective wavelengths demultiplexed by the demultiplexer; the multiplexer comprising a plurality of input waveguides for inputting signal lights,
- 15
- 20
- 25

one or plural output waveguides for outputting signal lights, and a slab waveguide having optical input/output characteristics set to predetermined ratios for the respective input waveguides with respect to the output

5 waveguides; the demultiplexer comprising a waveguide device comprising one or plural input waveguides for inputting signal lights, a plurality of output waveguides for outputting signal lights, and a slab waveguide having optical input/output characteristics set to predetermined

10 ratios for the respective output waveguides with respect to the input waveguides.

With the forty-fifth aspect of the present invention, the optical communication system, which is of a linear type, comprises optical transmitting means, a multiplexer for wavelength-division multiplexing the optical

15 signals of respective wavelengths transmitted by the light transmitting means, an optical transmission path for transmitting a wavelength-division multiplexed optical signal output from the multiplexer, a node disposed

20 in the optical transmission path and having a waveguide device, a demultiplexer for being supplied with the optical signal transmitted over the optical transmission path via the node and demultiplexing the optical signal into the optical signals of respective wavelengths, and optical

25 receiving means for receiving the optical signals of respective wavelengths demultiplexed by the demulti-

plexer. The multiplexer comprises a waveguide device according to the thirtieth aspect and sets optical input/output characteristics to predetermined ratios for the respective input waveguides with respect to the output waveguides that are connected to the output end of the slab waveguide. The demultiplexer comprises a waveguide device according to the twenty-ninth aspect and sets optical input/output characteristics to predetermined ratios for the respective output waveguides with respect to the input waveguides.

According to a forty-sixth aspect of the present invention, an optical communication system comprises: an annular transmission path having a plurality of nodes interconnected in a ring by a transmission path, for transmitting a multiplexed optical signal over the transmission path; each of the nodes having a first waveguide device for demultiplexing a multiplexed optical signal into optical signals of respective wavelengths; and a second waveguide device for multiplexing the demultiplexed optical signals of respective wavelengths, the first waveguide device comprising one or plural input waveguides for inputting signal lights, a plurality output waveguides for outputting signal lights, and a slab waveguide having optical input/output characteristics set to predetermined ratios for the respective output waveguides with respect to the input waveguides, the sec-

ond waveguide device comprising a plurality of input
waveguides for inputting signal lights, one or plural
output waveguides for outputting signal lights, and a
slab waveguide having optical input/output characteris-
tics set to predetermined ratios for the respective input
5 waveguides with respect to the output waveguides.

With the forty-sixth aspect of the present inven-
tion, the optical communication system, which is of an
annular type, comprises an annular transmission path hav-
ing a plurality of nodes interconnected in a ring by a
transmission path, for transmitting a multiplexed optical
signal over the transmission path, each of the nodes hav-
ing a first waveguide device for demultiplexing a multi-
plexed optical signal into optical signals of respective
15 wavelengths, and a second waveguide device for wave-
length-division multiplexing the demultiplexed optical
signals of respective wavelengths. The first waveguide
device comprises a waveguide device according to the
thirtieth aspect and sets optical input/output character-
istics to predetermined ratios for the respective input
20 waveguides with respect to the output waveguides that are
connected to the output end of the slab waveguide. The
second waveguide device comprises a waveguide device ac-
cording to the twenty-ninth aspect and sets optical in-
put/output characteristics to predetermined ratios for
25

the respective output waveguides with respect to the input waveguides.

According to a forty-seventh aspect of the present invention, an optical communication system comprises: optical transmitting means for transmitting optical signals of respective wavelengths parallel to each other; a multiplexer for multiplexing the optical signals of respective wavelengths transmitted by the light transmitting means; an optical transmission path for transmitting a multiplexed optical signal output from the multiplexer; a node disposed in the optical transmission path; a demultiplexer for being supplied with the optical signal transmitted over the optical transmission path via the node and demultiplexing the optical signal into the optical signals of respective wavelengths; and optical receiving means for receiving the optical signals of respective wavelengths demultiplexed by the demultiplexer; the multiplexer comprising a plurality of light sources for respective signals, a waveguide device having a plurality of input waveguides for inputting signal lights, one or plural output waveguides for outputting signal lights, and a slab waveguide having optical input/output characteristics set to predetermined ratios for the respective input waveguides with respect to the output waveguides, level detecting means for detecting levels of the signal lights input from the light sources to the

5 waveguide device, and level adjusting means for comparing
the levels of the signal lights detected by the level de-
tecting means with predetermined levels for the respec-
tive signal lights, and adjusting output levels of the
10 respective signal lights to set the levels of the signal
lights multiplexed by the waveguide device to desired
values; the demultiplexer comprising a waveguide device
having one or plural input waveguides for inputting sig-
nal lights, a plurality of output waveguides for output-
15 ting signal lights, and a slab waveguide having optical
input/output characteristics set to predetermined ratios
for the respective output waveguides with respect to the
input waveguides, and level adjusting means for being
supplied with the signal lights from the output
20 waveguides of the waveguide device, and adjusting output
levels of the signal lights to desired values.

With the forty-seventh aspect of the present inven-
tion, the optical communication system, which is of a
linear type, comprises: optical transmitting means, a
25 multiplexer for wavelength-division multiplexing the op-
tical signals of respective wavelengths transmitted by
the light transmitting means; an optical transmission
path for transmitting a wavelength-division multiplexed
optical signal output from the multiplexer; a node dis-
posed in the optical transmission path, a demultiplexer
for being supplied with the optical signal transmitted

over the optical transmission path via the node and demultiplexing the optical signal into the optical signals of respective wavelengths; and optical receiving means for receiving the optical signals of respective wavelengths demultiplexed by the demultiplexer. The multiplexer comprises a device according to the forty-fourth aspect, and the demultiplexer comprises a device according to the forty-third aspect, setting optical input/output characteristics to predetermined ratios.

10 According to a forty-eighth aspect of the present invention, an optical communication system comprises: an annular transmission path having a plurality of nodes interconnected in a ring by a transmission path, for transmitting a multiplexed optical signal over the transmission path; each of the nodes having a demultiplexer for demultiplexing a multiplexed optical signal into optical signals of respective wavelengths, and a multiplexer for multiplexing the demultiplexed optical signals of respective wavelengths; the demultiplexer comprising a
15 waveguide device having one or plural input waveguides for inputting signal lights, a plurality of output waveguides for outputting signal lights, and a slab waveguide having optical input/output characteristics set to predetermined ratios for the respective output
20 waveguides with respect to the input waveguides, and level adjusting means for being supplied with the signal

lights from the output waveguides of the waveguide device, and adjusting output levels of the signal lights to desired values; and the multiplexer comprising a plurality of light sources for respective signals, a waveguide
5 device having a plurality of input waveguides for inputting signal lights, one or plural output waveguides for outputting signal lights, and a slab waveguide having optical input/output characteristics set to predetermined ratios for the respective input waveguides with respect
10 to the output waveguides, level detecting means for detecting levels of the signal lights input from the light sources to the waveguide device, and level adjusting means for comparing the levels of the signal lights detected by the level detecting means with predetermined
15 levels for the respective signal lights, and adjusting output levels of the respective signal lights to set the levels of the signal lights multiplexed by the waveguide device to desired values.

With the forty-eighth aspect of the present invention,
20 tion, the optical communication system, which is of an annular type, comprises an annular transmission path having a plurality of nodes interconnected in a ring by a transmission path, for transmitting a wavelength-devision multiplexed optical signal over the transmission path,
25 each of the nodes having a demultiplexer for demultiplexing a multiplexed optical signal into optical signals of

5
respective wavelengths, and a multiplexer for multiplex-
ing the demultiplexed optical signals of respective wave-
lengths. The demultiplexer comprises a device according
to the forty-third aspect, and the multiplexer comprises
a device according to the forty-fourth aspect, ~~setting~~
optical input/output characteristics to predetermined ra-
tios.

10
According to the forty-fifth through forty-eighth
aspects of the present invention, input/output character-
istics can be changed or output characteristics can be
made flat without the need for attenuators, amplifiers,
or signal level adjusting means outside of the waveguide
device. Therefore, the overall system can be simplified,
made highly reliable, and reduced in cost.

15
The above and other objects, features, and advan-
tages of the present invention will become apparent from
the following description with reference to the accompa-
nying drawings which illustrate examples of the present
invention.

20

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view of an overall arrangement of
a conventional arrayed waveguide grating;

25
Fig. 2 is a plan view of an overall arrangement of
a slab waveguide of an arrayed waveguide grating accord-
ing to a first embodiment of the present invention;

Fig. 3 is an enlarged fragmentary plan view of a portion of the output end of the slab waveguide according to the first embodiment;

Fig. 4 is a cross-sectional view of the slab waveguide taken along an optical path leading to a compensation output waveguide positioned in a relatively peripheral region of the slab waveguide according to the first embodiment;

Fig. 5 is a cross-sectional view of the slab waveguide taken along an optical path leading to a compensation output waveguide positioned in a relatively central region of the slab waveguide according to the first embodiment;

Fig. 6 is a diagram showing the relationship between the cut length of a core layer and an increase in an optical loss caused by the cutting of the core layer in the slab waveguide according to the first embodiment;

Fig. 7 is an enlarged fragmentary plan view of a peripheral region of the output end of a slab waveguide of an arrayed waveguide grating according to a second embodiment of the present invention;

Fig. 8 is a view illustrative of how light is propagated in a compensation output waveguide, which does not perform output compensation, positioned in a relatively peripheral region of the slab waveguide according to the second embodiment;

Fig. 9 is a view illustrative of how light is propagated in a compensation output waveguide, which performs slight output compensation as compared with the compensation output waveguide shown in FIG. 8, of the slab waveguide according to the second embodiment;

Fig. 10 is a diagram showing the relationship between the axial misalignment of each output port and a loss caused thereby in the slab waveguide according to the second embodiment;

Fig. 11 is an enlarged fragmentary plan view of a portion of a slab waveguide of an arrayed waveguide grating according to a third embodiment of the present invention;

Fig. 12 is an enlarged fragmentary plan view showing the relationship between optical paths leading to respective output ports and the central axes of compensation output waveguides in slab waveguide according to the third embodiment;

Fig. 13 is a diagram showing the relationship between the angle of the central axis and a loss caused thereby in the slab waveguide according to the third embodiment;

Fig. 14 is an enlarged fragmentary plan view of a peripheral region of the output end of a slab waveguide of an arrayed waveguide grating according to a fourth embodiment of the present invention;

Fig. 15 is a diagram showing the relationship between the ratio between the spot size of a focused spot and the spot size in a waveguide mode of the waveguide, and a loss caused thereby in the slab waveguide according to the fourth embodiment;

Fig. 16 is an enlarged fragmentary plan view of a portion of a slab waveguide of an arrayed waveguide grating according to a fifth embodiment of the present invention;

Fig. 17 is a view showing, in principle, optical losses caused by a projecting portion of the output end of the slab waveguide according to the fifth embodiment;

Fig. 18 is a diagram showing the relationship between a shifted focus distance F and a loss caused thereby in the slab waveguide according to the fifth embodiment;

Fig. 19 is a view showing the manner in which optical signals can be multiplexed and demultiplexed using the arrayed waveguide grating according to the first embodiment;

Fig. 20 is a block diagram of a demultiplexer according to a sixth embodiment of the present invention;

Fig. 21 is a block diagram of a multiplexer according to a seventh embodiment of the present invention;

Fig. 22 is a block diagram of an optical communication system according to an eighth embodiment of the present invention;

Fig. 23 is a block diagram of a node of the optical communication system according to the eighth embodiment; and

Fig. 24 is a diagram showing, in principle, of the concept of a focal point according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

1st Embodiment

Fig. 2 shows in plan an output slab waveguide of an arrayed waveguide grating according to a first embodiment of the present invention. The arrayed waveguide grating according to the first embodiment has a structure which is basically the same as the conventional arrayed waveguide grating shown in Fig. 1. As shown in Fig. 2, the output slab waveguide, denoted by 101, has an input end connected to channel waveguide array 102 which sends light into output slab waveguide 101. Output waveguides 105 have waveguides 104, which correspond to output waveguides 14 shown in Fig. 1, having respectively ends connected to the output end of output slab waveguide 101 at a position opposite to the position where channel waveguide array 102 is connected to output slab waveguide

101. Light that has entered from channel waveguide array 102 into output slab waveguide 101 is propagated through output waveguide 105.

Fig. 3 shows in enlarged fragmentary plan a portion of the output end of output slab waveguide 101. Waveguides 104 of output waveguides 105 are divided into compensation waveguides 104_m through 104_{m+n} with the intensity of incoming light being compensated for and non-compensation waveguides 104_k through 104_{k+n} with the intensity of incoming light being not compensated for. Compensation waveguides 104_m through 104_{m+n} are designed to have optical signal levels compensated for, and can be used as monitoring waveguides. Non-compensation waveguides 104_k through 104_{k+n} are generally used in applications where a reduction in optical signal levels due to compensation is not desirable. All waveguides 104 of output waveguides 105 may be compensation waveguides.

Channel waveguide array 102 has core layer 111 for transmitting light entered from channel waveguide array 102. Core layer 111 is disposed in output slab waveguide 101 and extends to the position where output waveguides 105 are connected to output slab waveguide 101. As shown in Fig. 4, channel waveguide array 102 also has cladding layer 112 vertically (in the direction normal to the sheets of Figs. 2 and 3) sandwiching core layer 111 for thereby confining light in core layer 111. According to

the first embodiment, the portion of core layer 111 which corresponds to waveguides 104_m through 104_{m+n} is cut off in optical paths 113, providing a recess which is filled with cladding layer 112.

5 Figs. 4 and 5 show core layer 111 in cross section taken along two respective optical paths illustrated in Fig. 3. Specifically, the cross-sectional views in Figs. 4 and 5 of output slab waveguide 101 are taken respectively along optical path 113_{m+n} and optical path 113_{m+1} in
10 the direction normal to the sheets of Figs. 4 and 5. If core layer 111 were not cut off, the intensity of light emitted from channel waveguide array 102 shown in FIG. 2 and propagating along optical path 113_{m+n} leading to compensation waveguide 104_{m+n} shown in Fig. 4 would be
15 greater than the intensity of light emitted from channel waveguide array 102 shown in FIG. 2 and propagating along optical path 113_{m+1} leading to compensation waveguide 104_{m+1} shown in Fig. 5. These different intensities of light are equalized by adjusting the lengths L_{m+n} , L_{m+1} by
20 which core layer 111 is cut off respectively along optical paths 113_{m+n} , 113_{m+1} .

Specifically, the cut length L_{m+n} along optical path 113_{m+n} shown in Fig. 4 is relatively short, and a substantial portion of light emitted from a cut end of input
25 core layer 111_{IN} couple to output core layer 111_{OUT} and reaches compensation waveguide 104_{m+n} . However, the cut

length L_{m+1} along optical path 113_{m+1} shown in Fig. 5 is relatively large, and a substantial portion of light emitted from the cut end of input core layer 111_{IN} does not couple to output core layer 111_{OUT} . Therefore, the intensity of light that reaches compensation waveguide 104_{m+1} is greatly reduced.

The intensities of light in respective compensation waveguides 104_m through 104_{m+n} which are achieved if the core layer 111 is not cut off are measured or theoretically determined, and the optical paths 113 are partly cut off by lengths that are experimentally or theoretically determined in order to equalize the different intensities of light in respective compensation waveguides 104_m through 104_{m+n} . Core layer 111 may be cut off in desired regions by wet etching or dry etching. And the emission light from input core layer 111_{IN} may be coupled with compensation waveguide 104_m through 104_{m+n} directly to avoid in optical characteristics except optical loss characteristic change.

Fig. 6 shows the relationship between the cut length of a core layer and an increase in an optical loss caused by the cutting of the core layer in the slab waveguide according to the first embodiment. It can be seen from Fig. 6 that as the region cut in core layer 111 is longer, the loss of light reaching waveguides 104 is greater, attenuating light reaching waveguides 104. Some

arrayed waveguide gratings, or multiplexers or demulti-
plexers or optical communication systems which use ar-
rayed waveguide gratings may not be required to have flat
signal characteristics. For example, if amplifiers, not
5 shown, connected to the output ends of compensation
waveguides 104_m through 104_{m+n} do not have flat output
characteristics, then it is necessary to design total
output characteristics in view of the output characteris-
tics of the amplifiers. Actually, therefore, the inten-
10 sities of optical signals obtained by compensation
waveguides 104_m through 104_{m+n} are compensated for accord-
ing to the output characteristics that are needed.

2nd Embodiment

Fig. 7 shows in enlarged fragmentary plan a periph-
15 eral region of the output end of a slab waveguide of an
arrayed waveguide grating according to a second embodi-
ment of the present invention. The arrayed waveguide
grating according to the second embodiment has a struc-
ture which is basically the same as the conventional ar-
20 rayed waveguide grating shown in Fig. 1. As shown in
Fig. 7, output slab waveguide 131 has an input end con-
nected to channel waveguide array 102 which sends light
into output slab waveguide 131. Optical signals that has
propagated through output slab waveguide 131 are brought
25 into phase with each other and focused at respective out-
put port focusing positions P_{m+n} , P_{m+n-1} , P_{m+n-2} , The

optical signals that have been focused at respective out-
put port focusing positions P_{m+n} , P_{m+n-1} , P_{m+n-2} , ... are then
propagated through respective compensation waveguides
 132_{m+n} , 132_{m+n-1} , 132_{m+n-2} , ... serving as channel waveguides
5 which correspond to output waveguides 104 shown in Fig.
1.

The arrayed waveguide grating shown in Fig. 7 dif-
fers from the arrayed waveguide grating shown in Fig. 1
in that the core layer, not shown, of output slab
10 waveguide 131 is not cut off in optical paths, and the
extensions of the central axes of some or all of compen-
sation waveguides 132_{m+n} , 132_{m+n-1} , 132_{m+n-2} , ... are not
aligned, i.e., are out of axial alignment, with corre-
sponding output waveguide focusing positions P_{m+n} , P_{m+n-1} ,
15 P_{m+n-2} , In the present embodiment, the axial mis-
alignments are shown exaggerated for ease of understand-
ing.

Figs. 8 and 9 are illustrative of how light is
propagated in a compensation output waveguide, which does
20 not perform output compensation, positioned in a rela-
tively peripheral region of the slab waveguide according
to the second embodiment and in a compensation output
waveguide, which performs slight output compensation, of
the slab waveguide according to the second embodiment.
25 Compensation waveguides 132_{m+n} shown in Fig. 8 does not
perform output compensation for attenuating the light.

5 In Fig. 8, the extension of central axis 141_{m+n} of compensation waveguide 132_{m+n} is in alignment, i.e., is not axially misaligned, with output waveguide focusing position P_{m+n} in exactly the same manner as with the positional relationship between each input port of the ordinary output slab waveguide and the channel waveguide array. In the arrangement shown in Fig. 8, the light having a Gaussian intensity distribution which has been focused at output waveguide focusing position P_{m+n} well matches compensation waveguide 132_{m+n} and is propagated therethrough to its output end as indicated by arrow 142.

10 Compensation waveguide 132_{m+n-1} shown in Fig. 9, which is positioned adjacent to compensation waveguide 132_{m+n}, has its central axis 141_{m+n-1} displaced from corresponding output waveguide focusing position P_{m+n-1} by slight distance d_{m+n-1}. Because of the axial misalignment, the light having a Gaussian intensity distribution which has been focused at output waveguide focusing position P_{m+n-1} mismatches compensation waveguide 132_{m+n-1} when it is propagated therethrough, causing a light intensity loss (attenuation). As a result, even if the intensity of light focused at output waveguide focusing position P_{m+n-1} is greater than the intensity of light focused at output waveguide focusing position P_{m+n}, the axial misalignment may be set to a suitable value to equalize the intensity of light propagated through compensation waveguide 132_{m+n-1}.

to the intensity of light propagated through compensation waveguide 132_{m+n}. In this fashion, the intensities of light that are propagated through all compensation waveguides 132_{m+n}, 132_{m+n-1}, 132_{m+n-2}, ... can be equalized, thus providing flat output characteristics.

Fig. 10 shows the relationship between the axial misalignment of each output port and a loss caused thereby in the slab waveguide according to the second embodiment in order to obtain such flat output characteristics. As with the first embodiment, the second embodiment does not need to be limited to obtaining flat characteristics at the output end. Specifically, some arrayed waveguide gratings, or multiplexers or demultiplexers or optical communication systems which use arrayed waveguide gratings may not be required to have flat signal characteristics. For example, if amplifiers, not shown, connected to the final output ends, not shown, (output ends of output waveguides 14 shown in Fig. 1) from compensation waveguides 132_{m+n}, 132_{m+n-1}, 132_{m+n-2}, ... do not have flat output characteristics, then it is necessary to design total output characteristics in view of the output characteristics of the amplifiers. Actually, therefore, the intensities of optical signals obtained by compensation waveguides 132_{m+n}, 132_{m+n-1}, 132_{m+n-2}, ... are compensated for according to the output characteristics that are needed.

3rd Embodiment

Fig. 11 shows in enlarged fragmentary plan a portion of a slab waveguide of an arrayed waveguide grating according to a third embodiment of the present invention.

- 5 The arrayed waveguide grating according to the third embodiment has a structure which is basically the same as the conventional arrayed waveguide grating shown in Fig. 1. As shown in Fig. 11, output slab waveguide 161 is arranged to cause optical signals that has entered from
- 10 channel waveguide array 102 to be brought into phase with each other and focused at respective output waveguide focusing positions P_{m+n} , P_{m+n-1} , P_{m+n-2} , The arrayed waveguide grating has compensation waveguides 162_{m+n}, 162_{m+n-1}, 162_{m+n-2}, ... serving as output waveguides, not
- 15 shown, are disposed in association with respective output waveguide focusing positions P_{m+n} , P_{m+n-1} , P_{m+n-2} , Unlike the second embodiment, the extensions of the central axes of compensation waveguides 162_{m+n}, 162_{m+n-1}, 162_{m+n-2}, ... are not misaligned with respective output
- 20 waveguide focusing positions P_{m+n} , P_{m+n-1} , P_{m+n-2} , Instead, with the arrayed waveguide grating according to the third embodiment, the angles between optical paths 163_{m+n}, 163_{m+n-1}, 163_{m+n-2}, ... extending from the light emission points of channel waveguide array 102 to respective
- 25 output waveguide focusing positions P_{m+n} , P_{m+n-1} , P_{m+n-2} , ... and corresponding compensation waveguides 162_{m+n}, 162_{m+n-1},

162_{m+n-2}, ... are different depending on the amount by which the light is compensated for.

Fig. 12 shows in enlarged fragmentary plan the relationship between optical paths leading to respective output ports and the central axes of compensation output waveguides in slab waveguide according to the third embodiment. As with the first and second embodiments, compensation waveguide 162_{m+n} which is positioned in a relatively peripheral region of the output end of output slab waveguide 161 is designed to cause no light intensity loss, and the light intensity loss is increased successively from compensation waveguides 162_{m+n-1}, 162_{m+n-2}, ... toward the central region. Optical path 163_{m+n} connecting the channel waveguide array to output waveguide focusing position P_{m+n} and central axis 165_{m+n} of compensation waveguide 162_{m+n} form an angle θ_{m+n} of 0° therebetween. Thus, optical path 163_{m+n} and central axis 165_{m+n} are aligned with each other, so that the light having a Gaussian intensity distribution which has been focused at output waveguide focusing position P_{m+n} well matches compensation waveguide 162_{m+n} and is propagated therethrough to its output end with the best total coupling efficiency.

Compensation waveguide 162_{m+n-1} which is positioned adjacent to compensation waveguide 162_{m+n} has its central axis 165_{m+n-1} extending out of alignment with corresponding

optical path 163_{m+n-1}, but crossing corresponding optical path 163_{m+n-1} at a relatively small angle θ_{m+n-1} . Therefore, the light which has been focused at output waveguide focusing position P_{m+n-1} adjacent to output waveguide focusing position P_{m+n} mismatches compensation waveguide 162_{m+n-1} when it is propagated therethrough, causing a slight reduction in the total efficiency. As a result, even if the intensity of light focused at output waveguide focusing position P_{m+n-1} is greater than the intensity of light focused at output waveguide focusing position P_{m+n}, the angle θ_{m+n-1} may be set to a suitable value to equalize the intensity of light propagated through the output waveguide, i.e., compensation waveguide 162_{m+n-1}, to the intensity of light propagated through compensation waveguide 162_{m+n}.

The angle θ_{m+n-2} between central axis 165_{m+n-2} of compensation waveguide 162_{m+n-2} which is positioned adjacent to compensation waveguide 162_{m+n-1} toward the center and corresponding optical path 163_{m+n-2} is greater than the angle θ_{m+n-1} by a certain value. Thus, the coupling efficiency between output waveguide focusing position P_{m+n-2} and compensation waveguide 162_{m+n-2} is further reduced from the coupling efficiency between output waveguide focusing position P_{m+n-1} and compensation waveguide 162_{m+n-1}. The intensity of light propagated through compensation waveguide 162_{m+n-2} can be equalized to the intensity of

light propagated through compensation waveguide 162_{m+n-1} by setting the angle θ_{m+n-2} to a suitable value. In this manner, the intensities of light that are propagated through all compensation waveguides 162_{m+n} , 162_{m+n-1} , 162_{m+n-2} , ... can be equalized, thus providing flat output characteristics.

Fig. 13 shows the relationship between the angle of the central axis and a loss caused thereby in the slab waveguide according to the third embodiment. As with the first and second embodiments, the third embodiment does not need to be limited to obtaining flat characteristics at the output end. Specifically, some arrayed waveguide gratings, or multiplexers or demultiplexers or optical communication systems which use arrayed waveguide gratings may not be required to have flat signal characteristics. For example, if amplifiers, not shown, connected to the final output ends, not shown, (output ends of output waveguides 14 shown in Fig. 1) from compensation waveguides 162_{m+n} , 162_{m+n-1} , 162_{m+n-2} , ... do not have flat output characteristics, then it is necessary to design total output characteristics in view of the output characteristics of the amplifiers. Actually, therefore, the intensities of optical signals obtained by compensation waveguides 162_{m+n} , 162_{m+n-1} , 162_{m+n-2} , ... are compensated for according to the output characteristics that are needed.

4th Embodiment

Fig. 14 shows in enlarged fragmentary plan a peripheral region of the output end of a slab waveguide of an arrayed waveguide grating according to a fourth embodiment of the present invention. The arrayed waveguide grating according to the fourth embodiment has a structure which is basically the same as the conventional arrayed waveguide grating shown in Fig. 1. As shown in Fig. 14, as with output slab waveguide 101 shown in Fig. 1, output slab waveguide 191 is arranged to cause optical signals that has entered from a channel waveguide array, not shown, to be brought into phase with each other and focused at respective output waveguide focusing positions P_{m+a} , P_{m+a-1} , P_{m+a-2} , The optical signals that have been focused at respective output waveguide focusing positions P_{m+a} , P_{m+a-1} , P_{m+a-2} , ... are propagated through respective compensation waveguides 192_{m+a} , 192_{m+a-1} , 192_{m+a-2} ,

As with the third embodiment, output waveguide focusing positions P_{m+a} , P_{m+a-1} , P_{m+a-2} , ... are positioned respectively on the extensions of the central axes of corresponding compensation waveguides 192_{m+a} , 192_{m+a-1} , 192_{m+a-2} , Optical paths 193_{m+a} , 193_{m+a-1} , 193_{m+a-2} , ... extending from light emission points, not shown, on the channel waveguide array to respective output waveguide focusing positions P_{m+a} , P_{m+a-1} , P_{m+a-2} , ... are aligned with the central axis of corresponding compensation waveguides 192_{m+a} , 192_{m+a-1} , 192_{m+a-2} , With the arrayed waveguide grating

according to the fourth embodiment, waveguide widths W_{m+a} ,
 W_{m+a-1} , W_{m+a-2} , ... of respective compensation waveguides
 192_{m+a} , 192_{m+a-1} , 192_{m+a-2} , ... at their ends connected to
output slab waveguide 191 are different depending on the
5 amount by which the light is compensated for.

Specifically, the amount by which the light is com-
pensated for is adjusted based on the spot sizes of fo-
cused spots at respective output waveguide focusing posi-
tions P_{m+a} , P_{m+a-1} , P_{m+a-2} , ... and waveguide widths W_{m+a} , W_{m+a-1} ,
10 W_{m+a-2} , ... of corresponding compensation waveguides
 192_{m+a} , 192_{m+a-1} , 192_{m+a-2} ,

Fig. 15 shows the relationship between the ratio
between the spot size of a focused spot and the spot size
in a waveguide mode of the waveguide, and a coupling loss
15 caused thereby in the slab waveguide according to the
fourth embodiment. It can be seen from Fig. 15 that the
coupling loss is greater as the ratio between the spot
size of a focused spot and the spot size in a waveguide
mode of the waveguide differs more from 1. Since the
20 spot size of the focused spot is constant and the spot
size in the waveguide mode varies when the waveguide
width varies, waveguide widths W_{m+a} , W_{m+a-1} , W_{m+a-2} , ... of
corresponding compensation waveguides 192_{m+a} , 192_{m+a-1} ,
 192_{m+a-2} , ... are set to adjust the spot sizes of focused
25 spots and the spot sizes in the waveguide mode of the
waveguides. In this manner, waveguide widths W_{m+a} , W_{m+a-1} ,

W_{m+a-2} , ... of corresponding compensation waveguides 192_{m+a} ,
 192_{m+a-1} , 192_{m+a-2} , ... are set to suitable values to set the
intensities of optical signals propagated through compen-
sation waveguides (output waveguides) 192_{m+a} , 192_{m+a-1} ,
5 192_{m+a-2} , ... to desired characteristics such as flat char-
acteristics.

5th Embodiment

Fig. 16 shows in enlarged fragmentary plan a por-
tion of a slab waveguide of an arrayed waveguide grating
10 according to a fifth embodiment of the present invention.
The arrayed waveguide grating according to the fifth em-
bodiment has a structure which is basically the same as
the conventional arrayed waveguide grating shown in Fig.
1. As shown in Fig. 16, output slab waveguide 221 ac-
15 cording to the fifth embodiment has an output end par-
tially projecting toward output waveguides from cophasal
curve (a curve interconnecting output waveguide focusing
positions P_{m+n} , P_{m+n-1} , P_{m+n-2} , ... or output waveguide focus-
ing positions P_{m+a} , P_{m+a-1} , P_{m+a-2} , ... in the previous em-
20 bodiment) 223 which interconnects the connected ends of
non-compensation waveguides 222_k through 222_{k+n} , and com-
pensation waveguides 225_m through 225_{m+n} with light inten-
sities compensated for are connected to the projecting
portion of the output end. Specifically, the boundary
25 between output slab waveguide 221 and compensation
waveguides 225_m through 225_{m+n} partially projects from co-

phasal curve 223 toward the output waveguides. Instead of projecting from cophasal curve 223 toward the output waveguides, the output end of output slab waveguide 221 may be retracted toward the input end thereof.

5 Fig. 17 shows, in principle, optical losses caused by such a projecting portion of the output end of the slab waveguide according to the fifth embodiment. Light which has propagated through optical path 224_{m+n} that interconnects the channel waveguide array, not shown, and
10 output waveguide focusing position P_{m+n} well matches compensation waveguide 225_{m+n} disposed at output waveguide focusing position P_{m+n} , and is propagated therethrough to the output end thereof. At this time, the intensity level of the light is not compensated for.

15 Light which has propagated through optical path 224_{m+n-1} that interconnects the channel waveguide array and output waveguide focusing position P_{m+n-1} is focused at output waveguide focusing position P_{m+n-1} , but compensation waveguide 225_{m+n-1} is retracted by a given length (herein-
20 after referred to as "shifted focus distance") F_{m+n-1} in the direction in which the light is output. Therefore, the light having a Gaussian intensity distribution at output waveguide focusing position P_{m+n-1} is slightly distorted and propagated with an enlarged spot size through
25 compensation waveguide 225_{m+n-1}, causing a coupling loss due to a mismatch. Thus, by setting the shifted focus

distance F_{m+n-1} to a suitable value, it is possible to generate a coupling loss to cancel an increase in the light intensity caused at output waveguide focusing position P_{m+n-1} as compared with output waveguide focusing position P_{m+n} , thereby adjusting the intensity level of light propagated through compensation waveguide 225_{m+n-1} to the same intensity level of light propagated through compensation waveguide 225_{m+n}.

Compensation waveguide 225_{m+n-2} which is positioned adjacent to compensation waveguide 225_{m+n-1} toward the center is further retracted from corresponding output waveguide focusing position P_{m+n-2} toward the output waveguide by a greater shifted focus distance F_{m+n-2} . Therefore, the coupling efficiency between output waveguide focusing position P_{m+n-2} and compensation waveguide 225_{m+n-2} is further reduced from the coupling efficiency between output waveguide focusing position P_{m+n-1} and compensation waveguide 225_{m+n-1}. The intensity of light propagated through compensation waveguide 225_{m+n-2} can be equalized to the intensity of light propagated through compensation waveguide 225_{m+n-1} by setting the shifted focus distance F_{m+n-2} to a suitable value. In this manner, the intensities of light propagated through all compensation waveguides 225_{m+n}, 225_{m+n-1}, 225_{m+n-2}, ... can be equalized, thus providing flat output characteristics.

Fig. 18 shows the relationship between a shifted focus distance F and a loss caused thereby in the slab waveguide according to the fifth embodiment. As with the previous embodiments, the fifth embodiment does not need to be limited to obtaining flat characteristics at the output end. Specifically, some arrayed waveguide gratings, or multiplexers or demultiplexers or optical communication systems which use arrayed waveguide gratings may not be required to have flat signal characteristics. For example, if amplifiers connected to the output ends of compensation waveguides 225_{m+n} , 225_{m+n-1} , 225_{m+n-2} , ... do not have flat output characteristics, then it is necessary to design total output characteristics in view of the output characteristics of the amplifiers. Actually, therefore, the intensities of optical signals obtained by compensation waveguides 225_{m+n} , 225_{m+n-1} , 225_{m+n-2} , ... are compensated for according to the output characteristics that are needed.

Modifications of 1st through 5th Embodiments

Fig. 19 shows a general input/output relationship of a slab waveguide of an arrayed waveguide grating. In Fig. 19, those parts identical to those shown in Fig. 2 are denoted by identical reference numerals. In the first embodiment, optical signals from channel waveguide array 102 enter output slab waveguide 101, and demultiplexed optical signals are output from respective

5 waveguides 104 of output waveguides 105. Conversely,
waveguides 104 of output waveguides 105 may be used as
input waveguides, and channel waveguide array 102 may be
used as an output waveguide for multiplexing optical sig-
nals of various wavelengths or signals. Heretofore, it
has been necessary to adjust the intensity levels of
light at the input stage because the intensity levels of
light entering from a relatively central region of output
waveguides 105 are high. With output slab waveguide 101
10 according to the first embodiment being used as an in-
verted input/output configuration, such intensity levels
do not need to be adjusted, and the signal levels of mul-
tiplexed signals can be brought into an appropriate
range.

15 The arrangement for multiplying optical signals us-
ing the arrayed waveguide grating according to the first
embodiment has been described above. However, the con-
figuration shown in Fig. 19 is also applicable to the ar-
rayed waveguide gratings according to the second through
20 fifth embodiments for using these arrayed waveguide grat-
ings as multiplexers for optical signals as well as de-
multiplexers for optical signals.

6th Embodiment

25 Fig. 20 shows in block form a demultiplexer accord-
ing to a sixth embodiment of the present invention. As
shown in Fig. 20, the demultiplexer, denoted by 301, has

1 a waveguide device 303 for being supplied with optical
signal 302. Waveguide device 303 may be any of the ar-
rayed waveguide gratings according to the first through
fifth embodiments. Waveguide device 303 demultiplexes a
5 coupled optical signal and outputs demultiplexed optical
signals 305₁ through 305_N from respective output
waveguides 304₁ through 304_N. Monitoring amplifiers 306₁
through 306_N are connected to the respective output ends
of output waveguides 304₁ through 304_N. Monitoring am-
10 plifiers 306₁ through 306_N serve as AGC (Automatic Gain
Control) circuits for detecting signal levels of corre-
sponding optical signals 305₁ through 305_N and amplifying
or attenuating them to desired levels. Thus, optical
signals 305₁ through 305_N whose gains have been initially
15 adjusted by waveguide device 303 are finally adjusted in
gain by monitoring amplifiers 306₁ through 306_N, and out-
put as optical signals 307₁ through 307_N therefrom.

While it is possible for waveguide device 303 to
make flat the levels of optical signals 305₁ through
20 305_N, monitoring amplifiers 306₁ through 306_N are capable
of adjusting the levels thereof even if the output char-
acteristics of demultiplexer 301 as a whole are different
from that of waveguide device 303.

7th Embodiment

25 Fig. 21 shows in block form a multiplexer according
to a seventh embodiment of the present invention. As

shown in Fig. 21, the multiplexer, denoted by 301, has a plurality of semiconductor lasers 322₁ through 322_N for outputting optical signals of plural wavelengths. Optical signals 323₁ through 323_N output from respective semiconductor lasers 322₁ through 322_N are divided by dividers 324₁ through 324_N into two groups of optical signals. Optical signals 325₁ through 325_N of one group couple to waveguide device 326, which multiplexes optical signals 325₁ through 325_N into optical signal 327 and outputs multiplexed optical signal 327.

Optical signals 328₁ through 328_N of the other group which are divided by dividers 324₁ through 324_N have their signal levels detected by respective level detectors 329₁ through 329_N, which may comprise photodiodes. Based on detected results from level detectors 329₁ through 329_N, drive controllers 331₁ through 331_N associated with respective semiconductor lasers 322₁ through 322_N control output levels of laser beams emitted therefrom. As a result, the levels of the optical signals of respective wavelengths, which make up optical signal 327 output from waveguide device 326, can be set to appropriate levels.

If waveguide device 326 has its output characteristics compensated for to output a multiplexed signal whose level is equal to the equal levels of the optical signals coupled thereto, then the output characteristics of the

multiplexer 321 can be made flat without the use of drive
controllers 331₁ through 331_N. However, drive control-
lers 331₁ through 331_N are capable of adjusting output
characteristics if the multiplexer 321 is required to
5 have different output characteristics or make highly ac-
curate level adjustments.

8th Embodiment

Fig. 22 shows in block form an optical communica-
tion system according to an eighth embodiment of the pre-
10 sent invention. The optical communication system has op-
tical multiplexer (MUX) 402 which multiplexes optical
signals of N channels having respective wavelengths λ_1
through λ_N transmitted from optical transmitter 401 con-
nected to a SONET (Synchronous Optical Network) system,
15 not shown. A multiplexed optical signal 405 is amplified
by booster amplifier 403 and delivered into optical
transmission path 404. Optical multiplexer 402 comprise
the arrayed waveguide grating according to the first em-
bodiment. Multiplexed optical signal 405 is then ampli-
20 fied by in-line amplifiers 406, and applied via preampli-
fier 407 to optical demultiplexer (DMUX) 408, which de-
multiplexes multiplexed optical signal 405 into original
optical signals having respective wavelengths λ_1 through
 λ_N , which are received by optical receiver 409. Optical
25 transmission path 404 between in-line amplifiers 406 has
a suitable number of nodes (OADM) 411₁ through 411_N. Op-

tical signals of desired wavelengths are input to and output from these nodes 411₁ through 411_M.

Fig. 23 shows a node in block form. While first node 411₁ is shown in Fig. 23, second through Mth nodes 411₂ through 411_M are identical in structure to first node 411₁. Optical signal transmitted over transmission path 404 shown in Fig. 22 is applied to input arrayed waveguide grating (AWG) 421 of first node 411₁, which demultiplexes the optical signal into optical signals of N channels having respective wavelengths λ_1 through λ_N . The optical signals having respective wavelengths λ_1 through λ_N are dropped into node receivers 426 by 2-input, 2-output optical switches 422₁ through 422_N associated with respective wavelengths λ_1 through λ_N , and optical signals transmitted from node transmitters 424 are added to the optical signals having respective wavelengths λ_1 through λ_N . Optical signals output from 2-input, 2-output optical switches 422₁ through 422_N are also directly input to output arrayed waveguide grating 428. Output arrayed waveguide grating 428 is a device which is a structural reversal of input arrayed waveguide grating 421, and multiplexes optical signals of N channels having respective wavelengths λ_1 through λ_N into optical signal 420_s, which is transmitted over an optical transmission path 404.

Heretofore, attenuators for respective wavelengths λ_1 through λ_N are connected between 2-input, 2-output op-

tical switches 422₁ through 422_N and output arrayed
waveguide grating 428 for eliminating signal level ir-
regularities caused when multiplexed optical signal 405
passes through input arrayed waveguide grating 421 and
5 signal level irregularities of optical signal 405 for re-
spective wavelengths λ_1 through λ_N which have been multi-
plexed by output arrayed waveguide grating 428. In the
optical communication system according to the eighth em-
bodiment, as described above with respect to the first
10 embodiment and the modification of the first through
fifth embodiments, input arrayed waveguide grating 421
and output arrayed waveguide grating 428 are capable of
compensating for level variations between the waveguides.
In the present embodiment, therefore, attenuators which
15 have heretofore been required in applications where dy-
namic level compensation is not needed are not employed,
and the requirement for dynamic range characteristics of
the level compensators is reduced in applications where
dynamic level compensation is needed.

20 First node 411₁ shown in Fig. 23, and second through
Mth nodes 411₂ through 411_M, optical multiplexer 402, and
optical demultiplexer 408 shown in Fig. 22 employ arrayed
waveguide gratings. Therefore, in view of a demand for
an increased number of channels N for optical signal 405,
25 it is important to stabilize the wavelengths of laser
beams and monitor the output levels of the laser beams

which are output in multiple channels from the output slab waveguides of the arrayed waveguide gratings. As shown in Fig. 22, nodes 411₁ through 4111_n and optical transmitter 401 are associated with respective output monitoring control devices 431₁ through 431_s.

Modifications of 8th Embodiment

The eighth embodiment described above uses the arrayed waveguide grating according to the first embodiment. However, each of the arrayed waveguide gratings according to the second through fifth embodiments may be used in place of the arrayed waveguide grating according to the first embodiment in the eighth embodiment, providing a similar optical communication system. Furthermore, the multiplexer and the demultiplexer according to the sixth and seventh embodiments may be used instead of the above arrayed waveguide gratings.

Supplemental description

The preferred embodiments of the present invention have been described above. According to the present invention, desired optical input/output characteristics are achieved by producing optical losses in the slab waveguide of the arrayed waveguide grating or the waveguide connected thereto (including individual waveguides of the channel waveguide array). One approach to achieving such desired optical input/output characteristics is to use the degree of matching of a focal point

(9th and 10th aspects). The concept of a focal point in an arrayed waveguide grating will be described below.

Fig. 24 shows the manner in which coherent light emitted from a light source is propagated. When light is emitted to the left in Fig. 24 from point light source 501, the light is spread with a cophasal surface as indicated by the dotted lines. Since all points on the cophasal surface are always spaced an equal distance from point light source 501, the cophasal surface is concentric to point light source 501.

If light whose cophasal surface is arcuate is radiated from the left to the right in Fig. 24, then it propagates in the opposite direction and is focused at point light source 501, which serves as a focal point. While point light source 501 does not exist in reality, if a light source can be regarded as being positioned sufficiently far in view of optical radiation and convergence, then a light source having a width or a length can be handled as point light source 501.

For example, channel waveguide array 15 shown in Fig. 1 is of a structure for confining light three-dimensionally with the core vertically sandwiched by the cladding layer. If such a channel waveguide array is positioned far enough, then it can be handled as point light source 501 and radiation and convergence of light emitted therefrom can be considered. In an arrayed

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waveguide grating, the exit of the channel waveguide array is disposed in a circumferential pattern. If the waveguides are cophasal at the exit of the channel waveguide array, then it is possible to generate light
5 whose cophasal surface is approximately in a circumferential pattern and emit the light toward the center of the circumferential pattern. Thus, a focal point can be provided at the center of the circumferential pattern.

Even if the waveguides are not cophasal at the exit
10 of the channel waveguide array, a focal point is provided at a position off the center of the circumferential pattern if the waveguides are out of phase with each other. With a demultiplexer-type arrayed waveguide grating, the wavelengths propagated through the respective waveguides
15 of the channel waveguide array are out of phase with each other. Therefore, the optical signals of different wavelengths each other are focused at different positions in the output slab waveguide.

With a multiplexer-type arrayed waveguide grating,
20 it is preferable to focus the optical signals of different wavelengths each other at the same position regardless of the different wavelengths each other. In this case, the positions where the optical signals are applied need to be changed depending on the wavelength thereof in
25 order to cancel phase differences caused when the optical

signals are propagated through the channel waveguide array.

While preferred embodiments of the present invention have been described using specific terms, such description is for illustrative purposes only, and it is to
5 be understood that changes and variations may be made without departing from the spirit or scope of the appended claims.

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